

COSEWIC
Assessment and Status Report

on the

Yucca Moth
Tegeticula yuccasella

Non-pollinating Yucca Moth
Tegeticula corruptrix

Five-spotted Bogus Yucca Moth
Prodoxus quinquepunctellus

in Canada



ENDANGERED
2013

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada



COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

COSEWIC. 2013. COSEWIC assessment and status report on the Yucca Moth *Tegeticula yuccasella*, Non-pollinating Yucca Moth *Tegeticula corruptrix* and the Five-spotted Bogus Yucca Moth *Prodoxus quinquepunctellus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xix + 49 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

Previous report(s):

COSEWIC. 2002. COSEWIC assessment and update status report on the yucca moth *Tegeticula yuccasella* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 24 pp.

COSEWIC. 2006. COSEWIC assessment and status report on the Non-pollinating Yucca Moth *Tegeticula corruptrix* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 24 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

COSEWIC. 2006. COSEWIC assessment and status report on the Five-spotted Bogus Yucca Moth *Prodoxus quinquepunctellus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 31 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Production note:

COSEWIC would like to acknowledge Donna Hurlburt for writing the status report on Yucca Moth, *Tegeticula yuccasella*, Non-pollinating Yucca Moth, *Tegeticula corruptrix*, and Five-spotted Bogus Yucca Moth, *Prodoxus quinquepunctellus*, in Canada, prepared under contract with Environment Canada. This report was overseen and edited by Jennifer Heron, Co-chair of the COSEWIC Arthropods Specialist Subcommittee.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la Teigne du yucca (*Tegeticula yuccasella*), Teigne tricheuse du yucca (*Tegeticula corruptrix*) et la Fausse-teigne à cinq points du yucca (*Prodoxus quinquepunctellus*) au Canada.

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Yucca Moth — Cover page photo by G. G. Anweiler.

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COSEWIC Assessment Summary

Assessment Summary – May 2013

Common name

Yucca Moth

Scientific name

Tegeticula yuccasella

Status

Endangered

Reason for designation

Only two populations of the Non-pollinating Yucca Moth are known from an extremely small and restricted area. One site has a small and fluctuating moth population, while only a single adult was observed from 1998-2011 at the other site. This moth species is an obligate seed parasite, the larvae feeding on Soapweed seeds. It relies on the mutualistic relationship between the Soapweed and its pollinator Yucca Moth, as fruit production is needed by larvae of the Non-pollinating Yucca Moth. The loss of flowers or seeds as a result of ungulate herbivory is an ongoing threat, while in the long term Soapweed populations may be limited by the lack of fire and other disturbances that provide sites for the establishment of seedlings.

Occurrence

Alberta

Status history

Designated Endangered in April 2006. Status re-examined and confirmed in May 2013.

Assessment Summary – May 2013

Common name

Non-pollinating Yucca Moth

Scientific name

Tegeticula corruptrix

Status

Endangered

Reason for designation

Only two populations of the Non-pollinating Yucca Moth are known from an extremely small and restricted area. One site has a small and fluctuating moth population, while only a single adult was observed from 1998-2011 at the other site. This moth species is an obligate seed parasite, the larvae feeding on Soapweed seeds. It relies on the mutualistic relationship between the Soapweed and its pollinator Yucca Moth, as fruit production is needed by larvae of the Non-pollinating Yucca Moth. The loss of flowers or seeds as a result of ungulate herbivory is an ongoing threat, while in the long term Soapweed populations may be limited by the lack of fire and other disturbances that provide sites for the establishment of seedlings.

Occurrence

Alberta

Status history

Designated Endangered in April 2006. Status re-examined and confirmed in May 2013.

Assessment Summary – May 2013**Common name**

Five-spotted Bogus Yucca Moth

Scientific name

Prodoxus quinquepunctellus

Status

Endangered

Reason for designation

The Five-spotted Bogus Yucca Moth is known from only two sites in Canada, one of which was discovered in 2011. This moth species is an obligate stem borer on the stalks of Soapweed. Larval survival is dependent on the mutualistic relationship between the Soapweed and its pollinator Yucca Moth. The flowers on non-pollinated Soapweed stalks wither faster than pollinated stalks, resulting in almost complete mortality of immature life stages of Five-spotted Bogus Yucca Moth. The loss of flowers or seeds as a result of ungulate herbivory is an ongoing threat, while in the long term Soapweed populations may be limited by the lack of fire and other disturbances that provide sites for the establishment of seedlings.

Occurrence

Alberta

Status history

Designated Endangered in April 2006. Status re-examined and confirmed in May 2013.



COSEWIC **Executive Summary**

Yucca Moth
Tegeticula yuccasella

Non-pollinating Yucca Moth
Tegeticula corruptrix

Five-spotted Bogus Yucca Moth
Prodoxus quinquepunctellus

Wildlife Species Description and Significance

Yucca Moths are small white moths with an 18-27.5 mm wingspan. They have specialized maxillary tentacles used to handle the pollen of *Yucca* spp., with which they engage in an obligate pollination-seed predation mutualism.

Non-pollinating Yucca Moths are small white moths of the family Prodoxidae. They have a wingspan of 22.5-35.0 mm, and are mostly easily identified by their large size relative to other yucca moths. Non-pollinating Yucca Moths have a maxillary palp without a maxillary tentacle.

The Five-spotted Bogus Yucca Moth has a 11-21 mm wingspan. The forewings are white and can have up to 18 small dark spots.

Distribution

Yucca moths are found within Soapweed stands throughout the Great Plains from Texas north to Alberta and from the Rocky Mountains east to the Mississippi River. In Canada, Soapweed occurs at three locations: along the Milk River (Pinhorn, AB), its tributary, the Lost River (Onefour, AB) and Rockglen, SK. There are several single plants or small patches of Soapweed reported in southern Alberta and Saskatchewan; however, most of these plants were transplanted from native populations in Alberta or the United States.

Habitat

Soapweed occupies well-drained, sparsely vegetated, south-facing coulee slopes along the Milk River drainage in southeastern Alberta and in Rockglen, SK. The area has hot, dry summers and low precipitation with large daily temperature variation and weather extremes like high winds or heavy rain. Coulee habitat of this nature is rare and naturally limiting to the Soapweed. Intervening prairie, which is needed for range expansion, may have declined in quality for Soapweed because of fire suppression and lack of disturbance.

Biology

Adult Yucca Moths pollinate and lay eggs in Soapweed flowers. As larvae develop, they consume a portion of the fruit's seeds. Shortly before the seed pods split and disperse seeds, Yucca Moth larvae emerge from the fruit, burrow into the soil, and enter prepupal diapause. Most moths stay in diapause from 1-4 years. Adult moths live for about 4 days.

Non-pollinating Yucca Moths are obligate seed predators of Soapweed in Canada. They do not pollinate and lay eggs in early stage Soapweed fruit. After hatching, larvae feed on Soapweed seeds. In late summer, larvae emerge from the fruit, burrow into the soil, and enter prepupal diapause. They remain in this state for up to several years, before emerging from the soil as adults. Non-pollinating Yucca Moths rely on the mutualism between Yucca Moths and Soapweed for survival as fruit production is required for reproduction by the Non-pollinating Yucca Moth.

Five-spotted Bogus Yucca Moths are obligate stem-borers of Soapweed in Canada. Adults rest in flowers during the day and then oviposit in Soapweed flowering stalks during the evening. Eggs hatch within 9 days and larvae feed on stem tissue. Larvae enter diapause within the stem and remain for one to several winters before emerging as adults. Larval survival is dependent on the mutualism between Soapweed and Yucca Moths, as stalks without fruit wither and die resulting in almost complete mortality for Five-spotted Bogus Yucca Moth larvae.

Population Sizes and Trends

Yucca Moth abundance at Onefour ranges from 255 to about 10,000 annually. Data are short-term and are inadequate to infer population trends. Yucca Moth abundance at Pinhorn was assumed zero from 1997 to 2003, climbed to 5 in 2004, and in 2010 was at 36.

Numbers of Non-pollinating Yucca Moths fluctuate greatly among years and populations and adult moths are difficult to count. Available indices are insufficient to detect trends in abundance. Only a single adult was observed at Pinhorn from 1998 to 2011. Onefour abundance appears to be similar to other populations of Non-pollinating Yucca Moths at the northern edge of the species' range in Montana.

The Five-spotted Bogus Yucca Moth is apparently stable at the 2 locations in Alberta. At Onefour, the moth population is estimated at 500-1000s of individuals with no evidence of decline; the moth was only confirmed at Pinhorn in 2011 and is known to occur at lower densities than at Onefour.

Threats and Limiting Factors

Soapweed is naturally limited in Canada by its obligate relationship with the Yucca Moth, its habitat type, and its peripheral distribution and isolation from other populations in its range. Other non-anthropogenic threats include herbivory by wild ungulates and insects and extreme weather events like high winds or heavy rains.

The primary sources of anthropogenic threats to the expansion of Soapweed into adjacent habitats include habitat alteration and degradation through agriculture, oil and gas development and off-road vehicle use. Soapweed is collected for the horticultural trade and for medicinal use (threat currently negligible).

Protection, Status, and Ranks

Soapweed is listed under Canada's *Species at Risk Act* (SARA) as 'Threatened' and as 'Endangered' under Albertan legislation. It is the basis of an Alberta Recovery Plan and an Environment Canada Recovery Strategy. Soapweed is assessed as globally secure (G5) throughout its range and as critically imperiled in Canada (N1). Yucca Moth, Non-pollinating Yucca Moth and Five-spotted Bogus Yucca Moth are all considered globally secure (G4G5).

In Canada, the species occurs on public land that is managed by Alberta at the Pinhorn Grazing Reserve, and by Agriculture and Agri-Food Canada at the Onefour Research Substation. Its habitat is protected through critical habitat designation under SARA and regulations associated with Alberta natural areas.

Yucca Moth was assessed by COSEWIC as Endangered in 2002, Non-pollinating Yucca Moth and Five-spotted Bogus Yucca Moth were both assessed as Endangered in 2006.

TECHNICAL SUMMARY

Tegeticula yuccasella

Yucca Moth

Teigne du yucca

Range of occurrence in Canada (province/territory/ocean): Alberta

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2008) is being used)	Most adults are 1-4 yrs; it is speculated that some adults could be over 30 years of age through extended diapause
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? Since 1975, there has been an observed decline at Pinhorn; however, the population of Yucca Moths appears to be increasing slightly since 2004 due to recovery intervention, but as of yet the population is likely unsustainable.	Slight increase over last 2-3 generations
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased? Herbivory at Pinhorn is clearly a major contributor of Yucca Moth decline; however, it is unclear whether current interventions are adequate to sustain the population.	The causes are partially understood, are reversible but are unlikely to cease
Are there extreme fluctuations in number of mature individuals? Based on relative abundance measures, the number of mature individuals fluctuates up to 40 times among years; however, this may not increase the susceptibility to extinction given the possibility of extended prepupal diapause. Moth abundance in any particular year cannot readily be attributed to availability of Soapweed flowers.	Possibly, depends on the existence of extended diapause.

Extent and Occupancy Information

Estimated extent of occurrence	32 km ²
Index of area of occupancy (IAO)	12 km ²
Biological area of occupancy is 185 ha (1.85 km ²) based on critical habitat designation in Environment Canada (2011)	

Is the total population severely fragmented?	Yes
Yes, because the distance between the two sites can be considered large. The probability of yucca moths dispersing from Onefour to Pinhorn is low. Passive transport (via wind) is unlikely given the short longevity of moths, the apparent lack of directed flight and that the prevailing winds are in the opposite direction (west to east).	
However, it does not necessarily meet the condition that "...most (>50%) of its total area of occupancy is in habitat patches that are (1) smaller than would be required to support a viable population..." Onefour is sufficiently large enough (i.e. enough plants and holds majority of critical habitat) to support a yucca moth population over the long-term, but Pinhorn may not be able to in the face of wild ungulate herbivory.	
Number of locations*	2-3
If primary threat is development based on land ownership, there are two: Onefour and Pinhorn. If primary threat is grazing, there are three: Pinhorn – Soapweed not protected by exclosures, Pinhorn – Soapweed protected by exclosures, and Onefour.	
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	No
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Yes
Habitat quality has been declining giving the rare occurrence of fires and lack of other natural disturbances that promote seed germination and ensure host plant genetic viability.	
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Onefour, AB	100s to 1000s of adults
Varies annually from 225 to 1000s depending on Soapweed fruit production	
Pinhorn, AB	139 adults in 2011
Since 2004, varies from 5 to 139 in 2011. From 1998 through 2003, there was no known recruitment of Yucca Moths because there was no Soapweed fruit production at Pinhorn. It is unknown how many adult moths emerged from extended diapause in the soil during that time.	
Total	1000s; varies annually

* See Definitions and Abbreviations on [COSEWIC website](#) and [IUCN 2010](#) for more information on this term.

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Unknown
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Threats (actual or imminent, to populations or habitats)

Wild ungulate herbivory Habitat alteration Lack of disturbance
Other threats have been previously identified, but due to changes in management, their effects are thought to be negligible at present

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Apparently secure and widespread	
Is immigration known or possible?	Maybe
Not known to occur through natural means, although Yucca Moths are appearing in home gardens every 10 years or so; larvae can be transported for reintroduction	
Would immigrants be adapted to survive in Canada?	Yes
If from northern populations in Montana and North Dakota	
Is there sufficient habitat for immigrants in Canada?	Yes, within known locations of Soapweed, if herbivory is reduced
Is rescue from outside populations likely?	No
If occasional moths can find and occupy yucca patches, their abundance is not likely to be sufficient to ensure adequate levels of Soapweed fruit production to sustain a population	

Status History

COSEWIC: Designated Endangered in May 2002. Status re-examined and confirmed in May 2013.

Status and Reasons for Designation

Status: Endangered	Alpha-numeric code: B1ab(iii)+2ab(iii)
Reasons for Designation: Only two populations of the Yucca Moth are known from an extremely small and restricted area. This moth species has an obligate mutualistic relationship with Soapweed; Yucca Moth is the sole pollinator of Soapweed and its larvae depend on Soapweed seeds as a food source. One population may not be sustainable as it persists with human intervention that prevents severe herbivory of the flowers, fruits and stalks by wild ungulates. The Non-pollinating Yucca Moth larvae consume Soapweed seeds and compete with Yucca Moth for food. The loss of flowers or seeds as a result of ungulate herbivory is an ongoing threat, while in the long term Soapweed populations may be limited by the lack of fire and other disturbances that provide sites for the establishment of seedlings.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not Applicable.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1ab(iii)+2ab(iii) since the both the EO and IAO are under thresholds, the species is severely fragmented, is known to exist at less than 5 locations, and there is an observed continuing decline in habitat and host plant quality.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable since there is no evidence of decline in the number of mature individuals.
Criterion D (Very Small or Restricted Total Population): Meets D2 Threatened since only known at two locations.
Criterion E (Quantitative Analysis): None applicable.

TECHNICAL SUMMARY

Tegeticula corruptrix

Non-pollinating Yucca Moth

Teigne tricheuse du yucca

Range of occurrence in Canada (province/territory/ocean): Alberta

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2008) is being used)	Estimated 1-3 yrs, although could be over 30 years due to extended diapause
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? At Pinhorn, only a single adult moth has been observed since 1998; several cocoons were located in soil in 2000	Yes
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased? Decline expected from decline in Soapweed fruiting at Pinhorn from herbivory since 1970s	The causes are partially understood, are reversible but are unlikely to cease
Are there extreme fluctuations in number of mature individuals?	Possibly but unknown.

Extent and Occupancy Information

Estimated extent of occurrence	32 km ²
Index of area of occupancy (IAO) Biological area of occupancy is 185 ha based on critical habitat designation in Environment Canada (2011) 1.85 km ² (biological area of occupancy)	12 km ²
Is the total population severely fragmented?	Yes
Number of locations* If primary threat is development based on land ownership, there are two: Onefour and Pinhorn. If primary threat is grazing, there are three: Pinhorn – Soapweed not protected by exclosures, Pinhorn – Soapweed protected by exclosures, and Onefour.	2-3
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Maybe

* See Definitions and Abbreviations on [COSEWIC website](#) and [IUCN 2010](#) for more information on this term.

Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	Maybe
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	No
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Onefour, AB	100s to 1000s
Pinhorn Grazing Reserve, AB	1 adult in 2008
Total	100s to 1000s

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Unknown
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Threats (actual or imminent, to populations or habitats)

Wild ungulate herbivory Habitat alteration Lack of disturbance
Other threats have been previously identified, but due to changes in management, their effects are thought to be negligible at present

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Apparently secure and widespread to the south	
Is immigration known or possible?	
Not known to occur through natural means, although Yucca Moths are appearing in home gardens every 10 years or so; larvae can be transported for reintroduction	Maybe
Would immigrants be adapted to survive in Canada?	
If from northern populations in Montana and North Dakota	Yes
Is there sufficient habitat for immigrants in Canada?	Yes, within known populations of Soapweed, if herbivory is reduced
Is rescue from outside populations likely?	
Not through natural processes as the closest Soapweed populations is 200 km away in Montana with inhospitable intervening habitat	No

* See Definitions and Abbreviations on [COSEWIC website](#) and [IUCN 2010](#) for more information on this term.

Status History

COSEWIC: Designated Endangered in April 2006. Status re-examined and confirmed in May 2013.

Status and Reasons for Designation

Status: Endangered	Alpha-numeric code: B1ab(iii)+2ab(iii)
Reasons for designation: Only two populations of the Non-pollinating Yucca Moth are known from an extremely small and restricted area. One site has a small and fluctuating moth population, while only a single adult was observed from 1998-2011 at the other site. This moth species is an obligate seed parasite, the larvae feeding on Soapweed seeds. It relies on the mutualistic relationship between the Soapweed and its pollinator Yucca Moth, as fruit production is needed by larvae of the Non-pollinating Yucca Moth. The loss of flowers or seeds as a result of ungulate herbivory is an ongoing threat, while in the long term Soapweed populations may be limited by the lack of fire and other disturbances that provide sites for the establishment of seedlings.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1ab(iii)+2ab(iii) since the EO is less than 5,000km ² , the IAO is less than 500km ² , there is severe fragmentation, it is known to exist at less than 5 locations, and there is an observed continuing decline in habitat and host plant quality.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable, there is no evidence of decline in the number of mature individuals.
Criterion D (Very Small or Restricted Total Population): Meets D2 Threatened since only known at two locations.
Criterion E (Quantitative Analysis): None applicable.

TECHNICAL SUMMARY

Prodoxus quinquepunctellus

Five-spotted Bogus Yucca Moth

Fausse-teigne a cinq points du yucca

Range of occurrence in Canada (province/territory/ocean): Alberta

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2008) is being used)	1 – 6+ yrs; some individuals could be 30+ years of age due to extended diapause
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Not applicable
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
Recruitment has increased at Pinhorn due to protection of Soapweed from herbivory	
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased? Herbivory at Pinhorn is clearly a major contributor of Yucca Moth decline; however, it is unclear whether current interventions are adequate to sustain the population.	The causes are partially understood, are reversible but are unlikely to cease
Are there extreme fluctuations in number of mature individuals?	Possibly but unknown.

Extent and Occupancy Information

Estimated extent of occurrence	32 km ²
Index of area of occupancy (IAO)	12 km ²
Biological area of occupancy is 185 ha based on critical habitat designation in Environment Canada (2011)	1.85 km ² (biological area of occupancy)
Is the total population severely fragmented?	Yes
Number of locations* If primary threat is development based on land ownership, there are two: Onefour and Pinhorn. If primary threat is grazing, there are three: Pinhorn – Soapweed not protected by exclosures, Pinhorn – Soapweed protected by exclosures, and Onefour.	2-3
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	No

* See Definitions and Abbreviations on [COSEWIC website](#) and [IUCN 2010](#) for more information on this term.

Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	No
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	No
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Onefour, AB	100s to 1000s of adults
Pinhorn, AB	100s
Total	100s to 1000s; varies annually

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not applicable
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Threats (actual or imminent, to populations or habitats)

<p>Wild ungulate herbivory Habitat alteration Lack of disturbance</p> <p>Other threats have been previously identified, but due to changes in management, their effects are thought to be negligible at present</p>

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Apparently secure and widespread to the south	
Is immigration known or possible?	Maybe
Not known to occur through natural means, although Yucca Moths are appearing in home gardens every 10 years or so; larvae can be transported for reintroduction	
Would immigrants be adapted to survive in Canada?	Yes
If from northern populations in Montana and North Dakota	
Is there sufficient habitat for immigrants in Canada?	Yes, within known locations of Soapweed, if herbivory is decreased
Is rescue from outside populations likely?	No
Not through natural processes as the closest Soapweed populations is 200 km away in Montana with inhospitable intervening habitat	

* See Definitions and Abbreviations on [COSEWIC website](#) and [IUCN 2010](#) for more information on this term.

Status History

COSEWIC:

Designated Endangered in April 2006. Status re-examined and confirmed in May 2013.

Status and Reasons for Designation

Status: Endangered	Alpha-numeric code: B1ab(iii)+2ab(iii)
Reasons for designation: The Five-spotted Bogus Yucca Moth is known from only two sites in Canada, one of which was discovered in 2011. This moth species is an obligate stem borer on the stalks of Soapweed. Larval survival is dependent on the mutualistic relationship between the Soapweed and its pollinator Yucca Moth. The flowers on non-pollinated Soapweed stalks wither faster than pollinated stalks, resulting in almost complete mortality of immature life stages of Five-spotted Bogus Yucca Moth. The loss of flowers or seeds as a result of ungulate herbivory is an ongoing threat, while in the long term Soapweed populations may be limited by the lack of fire and other disturbances that provide sites for the establishment of seedlings.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1ab(iii)+2ab(iii) since the EO is less than 5,000km ² , the IAO is less than 500km ² , there is severe fragmentation, it is known to exist at less than 5 locations, and there is an observed continuing decline in habitat and host plant quality.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable as there is no evidence of decline in the number of mature individuals.
Criterion D (Very Small or Restricted Total Population): Meets D2 Threatened since only known at 2 locations.
Criterion E (Quantitative Analysis): None applicable.

PREFACE

This report bundles the best available information on three species of yucca moths that reside on a single species of host plant in Canada: Yucca Moth (*Tegeticula yuccasella*), Non-pollinating Yucca Moth (*T. corruptrix*) and the Five-spotted Bogus Yucca Moth (*Prodoxus quinquepunctellus*). There is also a companion status report on the host plant, the Soapweed (*Yucca glauca*). Throughout the text, Yucca Moth is capitalized when it refers to *Tegeticula yuccasella*. If yucca moth or yucca is not capitalized it refers more generally to the entire group of organisms.

Common Name	Scientific Name
Yucca Moth	<i>Tegeticula yuccasella</i>
Non-pollinating Yucca Moth	<i>Tegeticula corruptrix</i>
Five-spotted Bogus Yucca Moth	<i>Prodoxus quinquepunctellus</i>
Soapweed	<i>Yucca glauca</i>

Soapweed was assessed by COSEWIC in 1985 (Fairbarns 1985) and in 2000 (Csotonyi and Hurlburt 2000). Since Csotonyi and Hurlburt (2000), there has been considerable research on the population biology and ecology of Soapweed in Alberta and in the closest Montana populations. In the last 10 years, our knowledge of Soapweed demographics, intra- and interannual variation in reproduction, and the dynamics among Soapweed, its Yucca Moth pollinator and its other associates (Non-pollinating Yucca Moth, Five-spotted Bogus Yucca Moth, ants, aphids) have been greatly enhanced. COSEWIC assessed Yucca Moth in 2002 (COSEWIC 2002), Five-spotted Bogus Yucca Moth in 2006 (COSEWIC 2006a) and Non-pollinating Yucca Moth in 2006 (COSEWIC 2006b). A provincial recovery team was created for the Soapweed and the Yucca Moth (ASYMRT 2006), and significant strides in mitigating the impacts of human disturbance at the Onefour Research Substation and herbivory at the Pinhorn Grazing Reserve have been made since the last update status report (Environment Canada 2011). Critical habitat has been identified for Soapweed and Yucca Moth (Environment Canada 2011).



COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS (2013)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.



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The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Yucca Moth

Tegeticula yuccasella

Non-pollinating Yucca Moth

Tegeticula corruptrix

Five-spotted Bogus Yucca Moth

Prodoxus quinquepunctellus

in Canada

2013

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Yucca Moth (*Tegeticula yuccasella*), Non-pollinating Yucca Moth (*T. corruptrix*) and Five-spotted Bogus Yucca Moth (*Prodoxus quinquepunctellus*) are all Lepidoptera belonging to the superfamily Incurvarioidea and the family Prodoxidae.

Tegeticula yuccasella and *T. corruptrix*

Yucca moths were first described by Engelmann (1872a,b), who pointed out their association with yucca plants to Charles Riley, the State Entomologist for Missouri at the time. Riley (1892) and William Trelease (1893) described the moths first as *Pronuba* spp. in the late 1800s. Later, Walsingham (1903) and Coolidge (1909) found that the name *Pronuba* was preoccupied, the moth was renamed *Tegeticula yuccasella*, although some literature still retains the original genus name.

Historically, the genus *Tegeticula* was described as a species complex consisting of three species: *T. synthetic* which is monophagous on the Joshua tree (*Yucca brevifolia*), *T. maculata* on the Spanish bayonet (*Hesperoyucca whipplei*), and *T. yuccasella* as the pollinator for the other 30+ yucca species north of Mexico. Despite this classification, most researchers reported considerable morphological and behavioural variation within *T. yuccasella* and as a result, some researchers artificially separated coexisting species by oviposition behaviour (e.g. Wilson and Addicott 1998).

Using morphological and molecular data, Pellmyr (1999) completed a systematic revision of the yucca moths in the *T. yuccasella* complex and described 9 new pollinator species (as well as *T. yuccasella* Riley) and two non-pollinating "cheater" species of yucca moths (*T. intermedia* and *T. corruptrix*). Literature prior to 2000 uses *T. yuccasella* to refer to all 12 species.

Pollinating species of yucca moth, like *T. yuccasella*, have a mutualistic relationship with their host plants of the genus *Yucca*. They pollinate yucca plants and then oviposit into flower ovules. Their developing larvae only consume a portion of the viable seeds achieved through pollination, resulting in a net benefit in fitness for both species. Cheater yucca moths, such as the Non-pollinating Yucca Moth, oviposit in developing yucca fruit rather than in flowers and do not pollinate like the mutualistic species of yucca moths. The term "cheater" also refers to individuals of otherwise mutualistic species of yucca moths that oviposit but fail to pollinate. It is necessary to distinguish between cheating species and individual moths exhibiting cheating behaviour when reviewing the literature.

Using specimens collected from Onefour, Alberta and housed at the Canadian National Collection in Ottawa, Pellmyr (1999) identified the species of pollinating yucca moth residing in Soapweed (*Yucca glauca*) populations in southeastern Alberta as *Tegeticula yuccasella* (Riley). The presence of *T. corruptrix* was first recorded by Csotonyi and Hurlburt in 1998 (Csotonyi and Hurlburt 2000), and the identity of the species was confirmed by D. Hurlburt using the characters described in Pellmyr (1999).

Prodoxus quinquepunctellus

Five-spotted Bogus Yucca Moth, *P. quinquepunctellus* (Chambers), is the only species of the genus *Prodoxus* (the Bogus Yucca Moths) known to occur in Canada out of 10 described species.

Five-spotted Bogus Yucca Moth was originally described by V.T. Chambers in 1875. He named the moth *Hyponomeuta 5-punctella* and used it to challenge Riley's description of *T. yuccasella*. Riley described the morphological and behavioural differences between the species, and proposed *Prodoxus* as the new genus name for *P. quinquepunctellus* (Pellmyr 2003).

Five-spotted Bogus Yucca Moth was originally thought to be part of a complex of two separate species, based on the presence/absence of small dark spots on the forewings. The eastern unspotted form was named *P. decipiens* and the western spotted form, *P. quinquepunctellus*. Later, the presence of spotting was determined to be inconsequential, and *P. decipiens* was considered a junior synonym of *quinquepunctellus* and invalid (Davis 1967).

Morphological Description

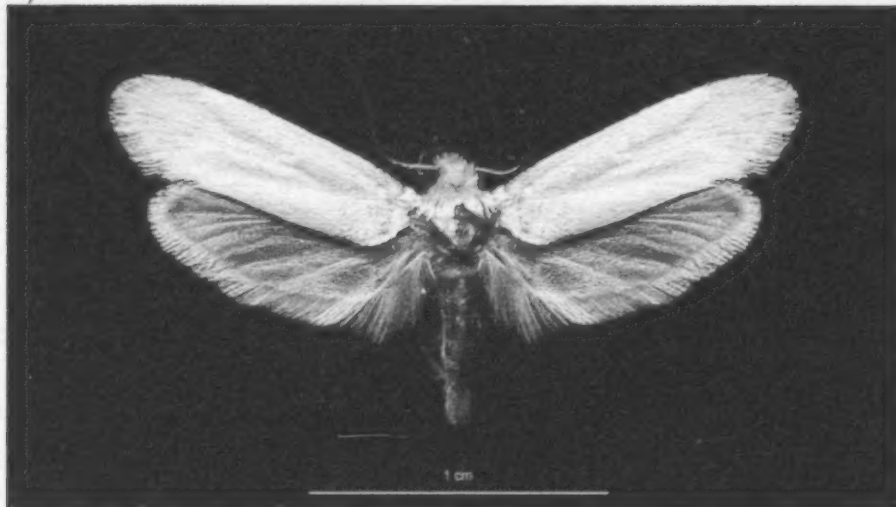
Yucca Moth (*T. yuccasella*), Non-pollinating Yucca Moth (*T. corruptrix*) and the Five-spotted Bogus Yucca Moth (*P. quinquepunctellus*) all reside with Soapweed flowers and may be found concurrently from early June through July. Adult Non-pollinating Yucca Moth may be distinguished from the other two species by their large relative size, absence of maxillary tentacles, and absence of black dots on their wings. They usually are not present until July at which time they begin to emerge. Five-spotted Bogus Yucca Moth is the smallest of the three, often occurs in relative abundance compared to the other two, and has small black dots on its wings. Maxillary tentacles are absent and they are often the earliest to emerge. Yucca Moths are moderate in size and have maxillary tentacles, which often hold yellow balls of pollen.

Yucca Moth and Non-pollinating Yucca Moth (genus *Tegeticula*) are characterized by a small wingspan of 15-35 mm, are non-descript, white or silvery, and have slender forewings. Females of pollinating species (i.e., Yucca Moth in Alberta) have maxillary tentacles with large numbers of sensory hairs. Tentacles are absent in males and in moth species that do not pollinate (i.e., Non-pollinating Yucca Moth in Alberta). There are subtle differences in colouring and morphology between the species, but microscopic examination of genitalia provides the most definitive identification.

Immature stages are poorly known and no morphological traits have been described enabling identification to species (Pellmyr 1999). Pupae of the genus *Tegeticula* have an acute spine on the head and spines on the back (Riley 1892). Larvae are less than 1 mm at hatching and reach 14 mm at maturity. At first they are translucent, but then turn yellowish and finally pinkish-red in colour. They have no prolegs, but thoracic legs are developed. Larvae undergo three moults (i.e. there are 4 instars) (Riley 1892). Eggs are club-shaped, translucent and about 2 mm in length (COSEWIC 2002).

Yucca Moths have a wingspan of 18-27.5 mm (Pellmyr 1999; Figure 1). The forewings are white on the dorsal side and mostly brown ventrally. The dorsal side of the hindwings is brownish grey while the underside is light brown (Pellmyr 1999). The head has white scales and females have a maxillary palp with a maxillary tentacle. The tentacles are tubular and membranous with many short, hooked hairs that hold pollen (Pellmyr and Leebens-Mack 2000). Males have a rudimentary tentacle. Antennae have 42-50 segments with a droplet-shaped terminal tentacle that is shorter than in other species. The thorax is mostly white and the legs amber. The abdomen is brown dorsally and white ventrally (Pellmyr 1999).

A)



B)



Figure 1. A) Adult Yucca Moth (*Tegeticula yuccasella*) from Onefour, AB. (Photo: G. G. Anweiler). B) Fourth instar Yucca Moth larvae from Onefour, AB. (Photo: D. Hurlburt).

Yucca Moth males have relatively small valvae with a broadly tapered cucullus and a slightly asymmetric pectinifer of 6-12 fused spines (Pellmyr 1999). The female ovipositor is 0.35-0.50 mm long with a high keel of fine teeth rising behind the tip (Riley 1892, Pellmyr 1999).

Non-pollinating Yucca Moths have a wingspan of 22.5-28.0 mm in males and 25.5-35.0 mm in females (Figure 2). The dorsal surface of the forewings and hindwings is white and the ventral surface mostly brown. The head has white scales and a maxillary palp, but maxillary tentacles are not present. Antennae have about 50-60 segments and are half as long as the forewing. The thorax has white scales and the legs are amber. The abdomen is tan dorsally and white ventrally (Pellmyr 1999).

Male valvae have a tapering cucullus and asymmetric pectinifer of 6-15 fused spines. In females, the ovipositor is 0.08-0.10 mm with a high keel of fine teeth (Pellmyr 1999).

Five-spotted Bogus Yucca Moths are small with female wingspans 11.5 – 21.0 mm and those of males, 11.0 – 16.5 mm (Althoff *et al.* 2001; Figure 3). The dorsal surface of the forewings is usually white with up to 18 small, dark spots. The ventral surface of the forewings is medium brown. The dorsal surface of the hindwings has sparser scales than the forewings, is grey to almost white, and usually appears darker than the forewings (Davis 1967). The head, thorax and abdomen are covered in white scales. The hindwing ventral surface is brownish-grey and sparsely scaled. The fringes of both sets of wings are white.

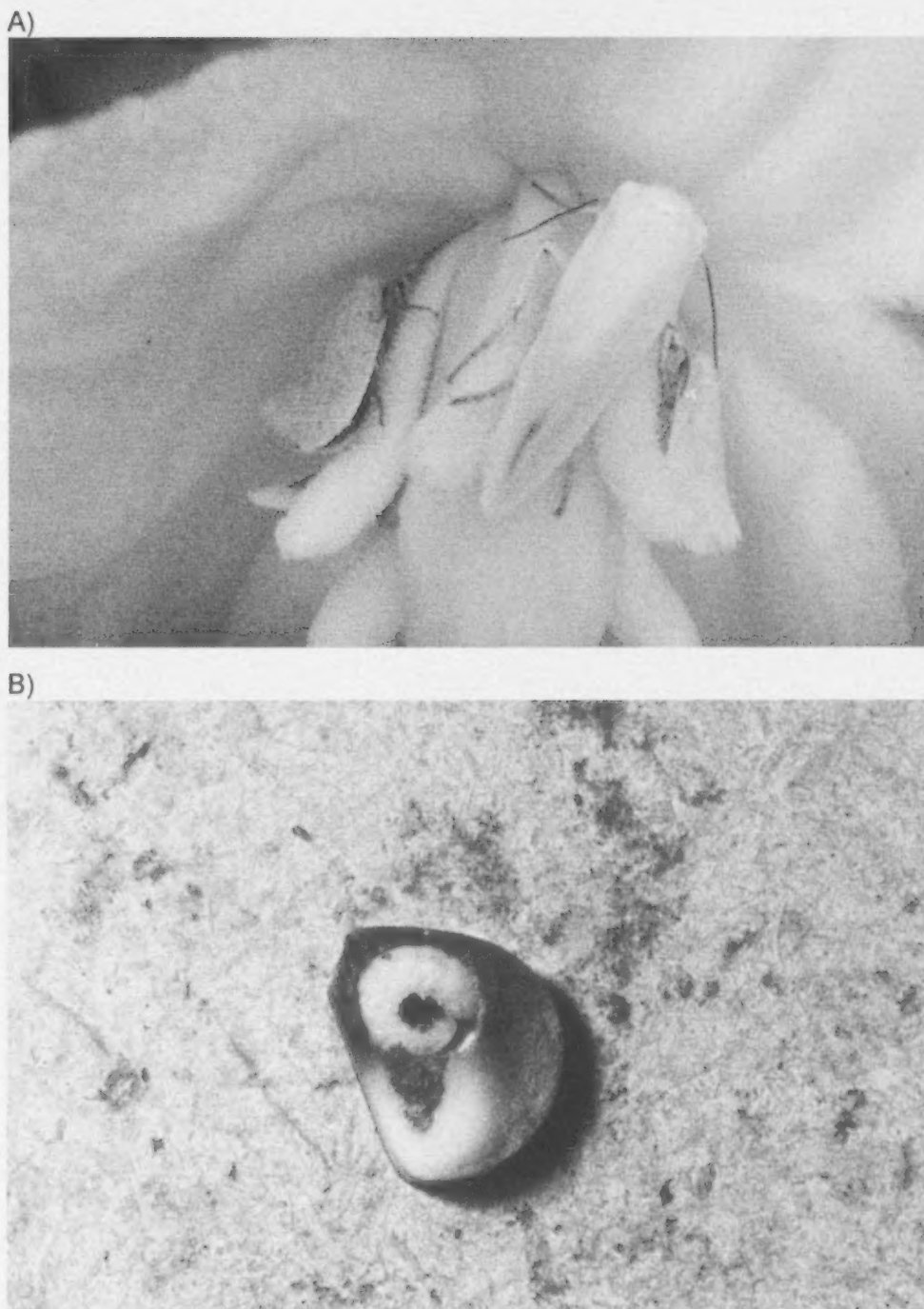


Figure 2. A) Adult Non-pollinating Yucca Moth (*Tegeticula corruptrix*, centre) flanked by adult Five-spotted Bogus Yucca Moths (*Prodoxus quinquepunctellus*) in a Soapweed (*Yucca glauca*) flower (Onefour, Alberta; July 2000). B) *Tegeticula corruptrix* larva (2nd instar) in Soapweed (*Yucca glauca*) seed (Onefour, Alberta; August 2003). (Photos: D. Hurlburt.)

A)



B)

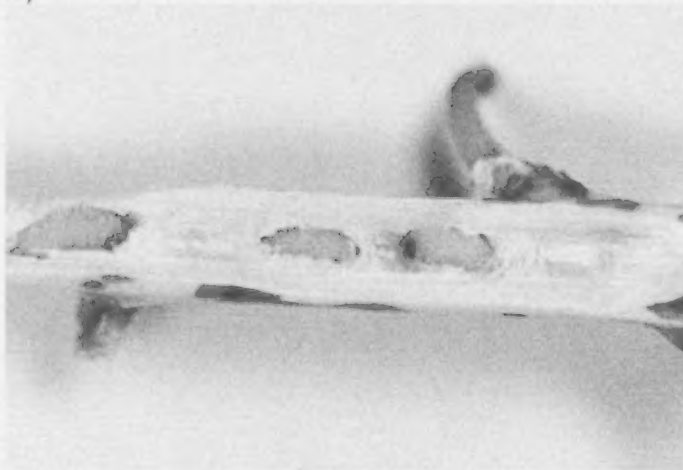


Figure 3. A) Adult female Five-spotted Bogus Yucca Moth (*Prodoxus quinquepunctellus*) ovipositing on the flowering stalk of Soapweed (*Yucca glauca*). B) Five-spotted Bogus Yucca Moth larvae and feeding tunnels inside a Soapweed flowering stalk. (Photos by R. Snell.)

In males, the valvae are mostly linear with the outer margin of the cucullus curved outwards with 2-5 short spines (Althoff *et al.* 2001). Females have an ovipositor 4.0-6.8 mm long (Althoff *et al.* 2001) with a stout shaft with a dorsal ridge with 6-8 coarse teeth (Davis 1967).

Immature stages of Five-spotted Bogus Yucca Moths have few morphological characteristics that distinguish them from other yucca moths, other than their presence within flowering stalks of *Yucca* spp. Eggs are soft, white and usually elongated with both ends rounded, although shape can be variable. The egg has no pedicle, is about 0.4 mm in length and 0.1 mm in girth (Davis 1967). The legless larvae are 5-7 mm long, are whitish in the early stages and turn a pale green at maturity (Riley 1892, Davis 1967, COSEWIC 2006a). Pupae are smooth with a prominent frontal 'beak' which aids creating exit holes in the flowering stalk.

Population Spatial Structure and Variability

Although geographic variation in integument colour and wing shape has been observed in Yucca Moths, measures of genitalia do not show evidence of structured variation (Pelmyr 1999). No data are available for similar variables for either of the other two species.

Designatable Units

There is only one subspecies of each of Yucca Moths, Non-pollinating Yucca Moths and Five-spotted Bogus Yucca Moths are recognized in Canada and there are no distinctions that warrant consideration of multiple designatable units. This report is based on a single designatable unit for each of the three species.

Special Significance

Yucca Moth engages in an obligate mutualistic relationship with its host plant, Soapweed (*Y. glauca*), as its sole pollinator. The fitness of both species is enhanced from their interactions. There are few interspecific relationships of this nature occurring worldwide and this may be the only example of an obligate, rather than facultative mutualism, among free-living plant-pollinator species in Canada.

Soapweed is also the sole host to several other rare and/or endangered species of Lepidoptera, in addition to the Yucca Moth. Non-pollinating Yucca Moth and Five-spotted Bogus Yucca Moth use Soapweed fruit and inflorescences respectively as oviposition sites, and both have been listed as 'Endangered' on Schedule 1 of the *Species at Risk Act* (SARA). Strecker's Giant Skipper (*Megathymus streckeri* (Skinner)) relies on the leaves, stems and roots of the Soapweed for larval development (Anweiler 2005). The species has ranked highly on COSEWIC's Candidate list but has not been assessed. This web of 5 highly-interdependent, specialized organisms, plus their complex interactions with ants and aphids (Perry 2001; Perry *et al.* 2004; Snell 2008a; Snell 2008b), epitomizes the need to collectively assess and preserve food web interactions. Other rare or listed species, such as Greater Short-horned Lizard (*Phrynosoma hernandesi*), also use Soapweed habitat (Tuttle 2005).

Soapweed and Yucca Moths have unique characteristics in Alberta that allow both the species and the mutualism between them to persist despite highly variable biological and environmental conditions at the northern edge of their ranges. At the northern edge of its range (generally, north of the Missouri River), the Yucca Moth lays its eggs throughout the ovary rather than in the centre, which enhances egg survival (Hurlburt 2004). Yucca species in the central portions of their distributions regulate yucca moth egg densities so that larvae do not consume all viable yucca seeds. Repeated ovipositions in the centre of the ovary tend to destroy eggs that were previously deposited, reducing larval densities (Shapiro and Addicott 2003). In northern populations of Soapweed, yucca moths distribute their egg throughout the ovary which appears to enhance larval survival, presumably because there is less destruction of eggs through oviposition (Hurlburt 2004).

Soapweed in Alberta have the longest flowering seasons documented among any *Yucca* spp., which allows for some pollination and seed set to occur even when moth emergence is delayed (Hurlburt 2004). The plants can regulate low densities of Yucca Moths by selectively abscising fruit with fewer moth eggs and only retaining those which will result in more larvae, a process deemed 'reverse selective abscission' which has only been described in northern populations of Soapweed (Hurlburt 2004). Most yuccas abscise fruit with more eggs presumably as a means of decreasing seed consumption, i.e. "selective abscission" (Shapiro and Addicott 2004). Unlike most yuccas, Soapweed in Alberta is not restricted to outcrossing and can readily retain selfed flowers (with the Yucca Moth as the vector) with no apparent effect of inbreeding depression on progeny (Hurlburt 2004). This appears to be a northern range edge phenomenon, indicative of local adaptation likely of evolutionary importance. These attributes are worthy of protection as a unique and crucial element to Canada's biodiversity and the local adaptations may be globally important.

Canadian populations of yucca moths are part of a group of organisms that are naturally located at the northern periphery of their ranges in southeastern Alberta. Presumably many of these populations were restricted to warmer regions as ice retreated after the hypsithermal. These peripheral populations of yucca moths and Soapweed are expected to be on the leading edge of range expansion and may be adapted to a greater variety of environmental conditions than those experienced by populations at the centre of the species' ranges. These populations may also be more resilient to anthropogenic disturbance or climate change than others (Lesica and Allendorf 1995; Lomolina and Channell 1998).

DISTRIBUTION

Global Range

Yucca Moth

Yucca Moth inhabits *Yucca* spp. populations throughout the Great Plains from southern Texas to southern Alberta and possibly southern Ontario, to areas east of the Plains to Michigan and Connecticut (Figure 4; Pellmyr 1999). The moth is known from southern Ontario because of specimens in the Canadian National Collection of Insects at Agriculture and Agri-Food Canada (AAFC); however, it is believed that these specimens arose from ornamental Yuccas. Yucca Moth pollinates several species of *Yucca*, in addition to Soapweed, which results in a larger North American distribution than its Canadian host. The Ontario moths are considered artificial introductions associated with a horticultural host and thus do not fall under the purview of COSEWIC.



Figure 4. Distribution of the Yucca Moth, *Tegeticula yuccasella*, in North America.

Non-pollinating Yucca Moth

Non-pollinating Yucca Moth has been reported in Yucca populations from Mexico and southern Texas north to Alberta, and from California east to Nebraska (Figure 5; Pellmyr 1999; Crabb and Pellmyr 2004). The distribution of the species is poorly known since it was only formally described in 1999 (Pellmyr 1999). It is not known from any manipulated or otherwise artificial populations of *Yucca* spp. in Canada.

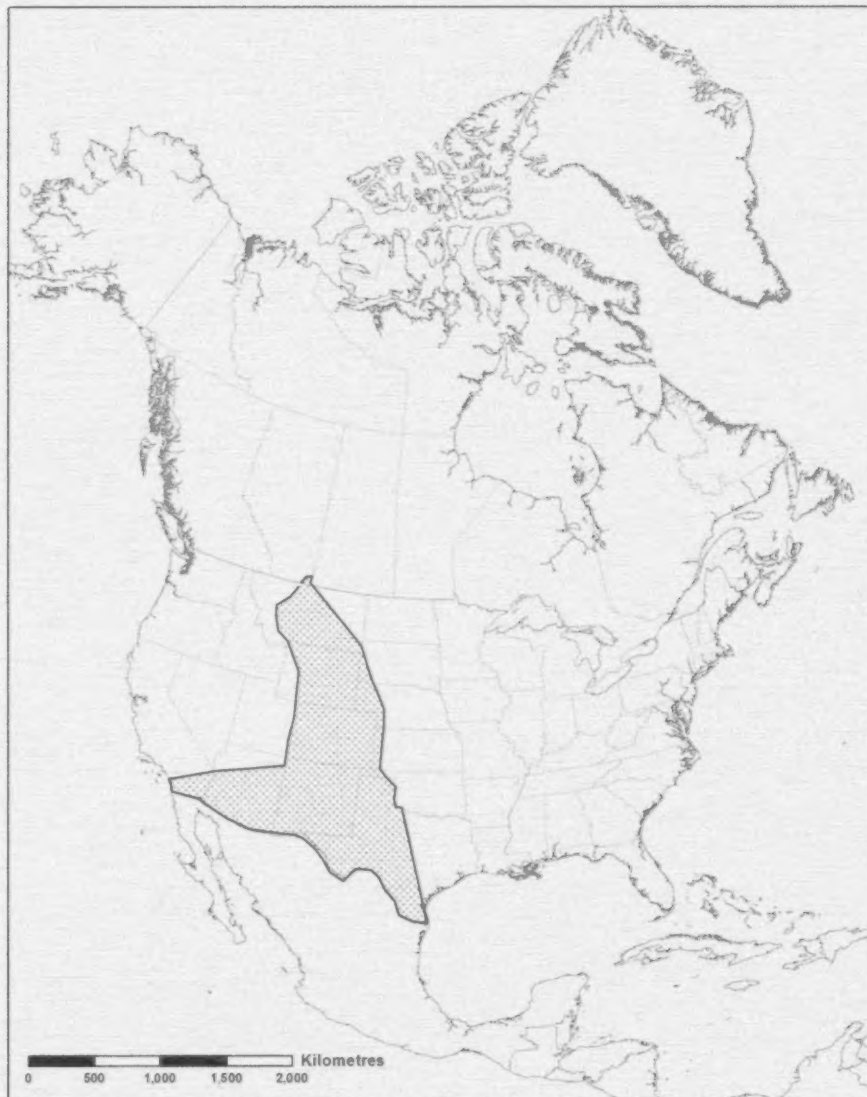


Figure 5. Distribution of the Non-pollinating Yucca Moth, *Tegeticula corruptrix*, in North America.

Five-spotted Bogus Yucca Moth

Five-spotted Bogus Yucca Moth is a widespread member of the genus which occupies 15 *Yucca* species (Powell 1992). The species is expected to occur from Texas and the Gulf of Mexico to southern Alberta and from the Atlantic coast of the United States to the Great Plains (Figure 6). It was collected in southern Ontario (specimens housed in the Canadian National Collection of Insects) in the 1930s and 1950s, but it is thought these were reared from cultivated *Yucca filamentosa*, and as with Ontario populations of the Yucca Moth, do not fall under COSEWIC's purview.

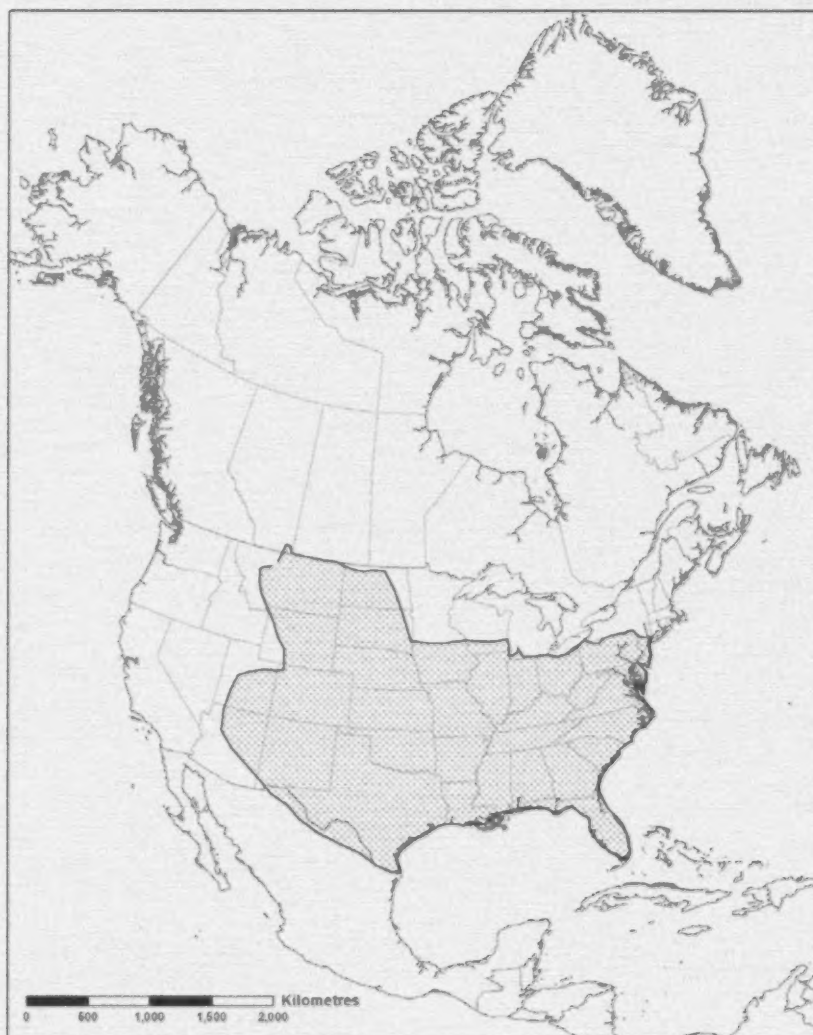


Figure 6. Distribution of the Five-spotted Bogus Yucca Moth, *Prodoxus quinquepunctellus*, in North America. Map adapted from Davis (1967) and Althoff *et al.* (2001).

Canadian Range

Yucca Moth, Non-pollinating Yucca Moth and Five-spotted Bogus Yucca Moth are found in native Soapweed at two locations in southeastern Alberta. One population is near Onefour, AB along the Lost River drainage, a tributary of the Milk River. This population is within the boundaries of the Onefour Research Substation managed by Agriculture and Agri-Food Canada. The second population is on the Pinhorn Grazing Reserve south of Manyberries (Figure 7).

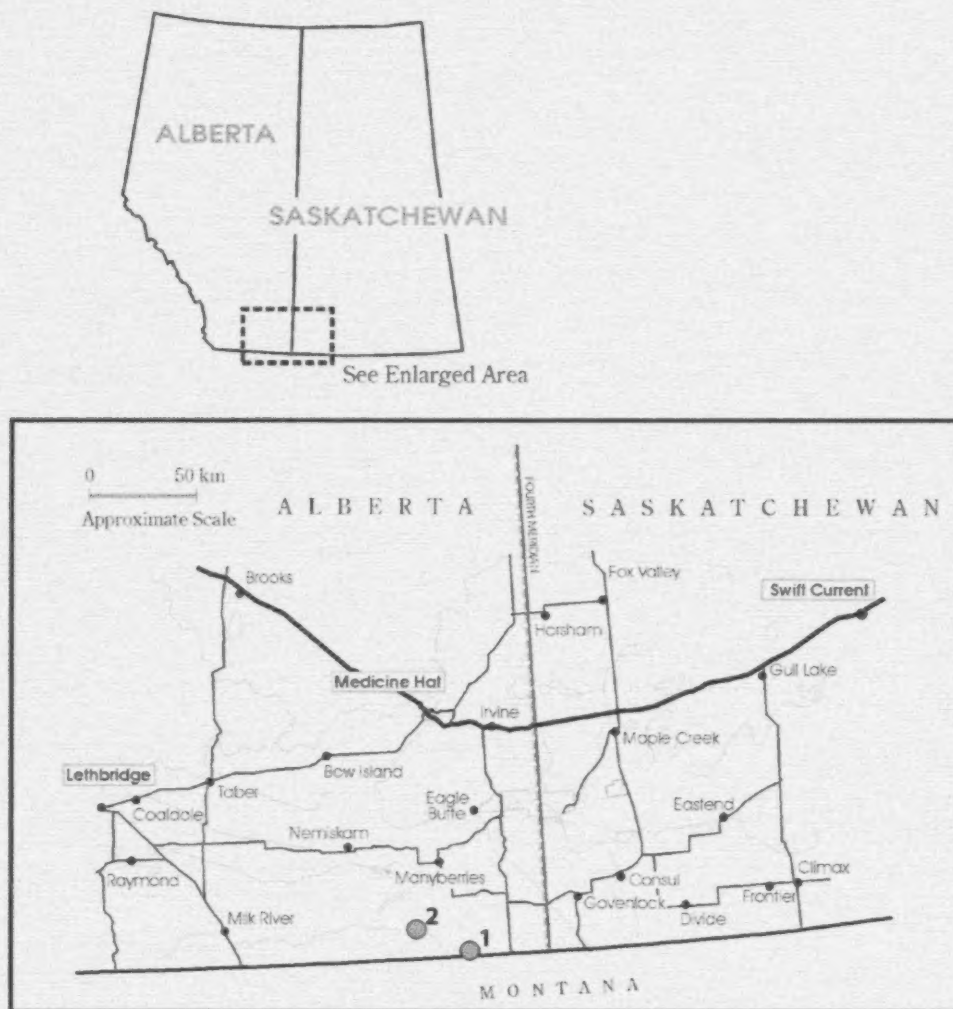


Figure 7. Distribution of native Soapweed (*Yucca glauca*), Yucca Moth (*Tegeticula yuccasella*), Non-pollinating Yucca Moth (*T. corruptrix*) and Five-spotted Bogus Yucca Moth (*Prodoxus quinquepunctellus*) in Canada. Site 1 is along the Lost River at Onefour, AB. Site 2 is along the Milk River on the Pinhorn Grazing Reserve, AB. (Map from COSEWIC 2002.)

Several isolated, small patches of Soapweed, reported to be transplants originating from Onefour, Pinhorn or the United States, occur across southern Alberta (Fairbarns 1985; Csotonyi and Hurlburt 2000; Hurlburt 2001; Hurlburt 2007; Saunders and Ernst 1998) and Saskatchewan (Fairbarns 1985; Hurlburt 2001). Some of those transplanted patches of native Soapweed host Yucca Moths, resulting in fruit set on an almost annual basis, including plants at Etzikom Windmill Museum, Etzikom AB, Police Point Park, Medicine Hat, AB and in several private gardens near Pinhorn and Onefour (ASYMRT 2006; Foreman *et. al.* 2006). There are six Soapweed plants in natural habitat at Rockglen, SK. Enlarged pedicels on a single old flowering stalk are not adequate evidence of Yucca Moth presence, and it is thought that this Soapweed patch does not contain a sustainable population of moths.

Pollinating species of yucca moths (species unverified) have also been reported in horticultural *Yucca* spp. at Lethbridge, AB (Johnson pers. comm. 2011, Dormaar pers. comm. 1999, Harris pers. comm. 2011), Magrath, AB (Cunningham pers. comm. 2011), Olds, AB (Pohl *et al.* 2010), Fox Valley, SK (Milner 1977), Normandale, ON, Queenston, ON, Vineland, ON and Simcoe, ON (presence in Ontario based on specimens from CNC collections and anecdotal references to yucca fruit set in gardens on miscellaneous gardening newsgroups). The identity of the moth species present at any of these sites has not been confirmed as they had been observed in the larval stage within mature fruit. It is possible that these moths may have originated from individuals transported in the soil of potted plants and could be of a different pollinating species depending upon their origin. It is also possible that, on occasion, adult Yucca Moths dispersed to some of the geographically closer among these sites from other yucca patches. It is unlikely that small, isolated patches of *Yucca* plants could support the establishment of a viable population of Yucca Moths.

The estimated extent of occurrence of Yucca Moth, Non-pollinating Yucca Moth and Five-spotted Bogus Yucca Moth is 32 km² which is the same range extent as Soapweed. The index of area of occupancy (IAO) is 12 km² and the biological area of occupancy is 185 ha based on critical habitat designation in Environment Canada (2011)

Number of Locations

Based on the threat of development based on land ownership, there are 2 locations, Onefour and Pinhorn. Based on the threat of ungulate herbivory, there are 2 – 3 locations: two at Pinhorn based on wild ungulate herbivory (fenced and not fenced Soapweed populations) and one at Onefour (non-threatening grazing by wild ungulates, but some minor domestic cattle grazing). At present, grazing by cattle at Onefour is negligible, but could increase with increased stocking density or grazing by cattle during the flowering season.

Search Effort

From 1998-2011, several thousand search hours have been expended looking for native Soapweed populations, and their yucca moths, in Alberta and Saskatchewan. Although the search has not been systematic, most areas of suitable habitat, particularly along the Milk River have been searched. To date, additional search effort has not resulted in the identification of new Soapweed populations although the plant is readily detectable particularly during flowering. Because Soapweed is readily identifiable by the public and particularly visible during flowering, most new records are provided by non-biologists or naturalists as incidental observations.

In 2007 and 2008, a media campaign was launched to encourage the public to report yuccas that had fruited in gardens, as a means of tracking the prevalence of Yucca Moth in Alberta (Johnson pers. comm. 2011). Despite the increase in attention through newspapers, newsletters and websites across southern Alberta, no new native plants or populations were reported, although incidents of fruiting in gardens were documented in Lethbridge and Magrath in 2007 (Johnson pers. comm. 2011, Cunningham pers. comm. 2011, Harris pers. comm. 2011).

In 1999, about 40 samples of soil surrounding Soapweed plants at the Pinhorn Grazing Reserve were collected and sifted to verify the presence of yucca moths in prepupal diapause. Four cocoons containing live Non-pollinating Yucca Moths were found, but no Yucca Moth cocoons were located (Hurlburt unpubl. data).

HABITAT

Habitat Requirements

In Alberta, yucca moths are found in Soapweed stands that are restricted to the Dry Mixedgrass Subregion (Natural Regions Committee 2006). This Subregion has very warm summers, high solar gains, long growing seasons and low precipitation with large daily temperature variation and weather extremes. The mean growing season temperature is approximately 16 °C, the regional frost-free season is 100-120 days and the growing season about 180-200 days (Fairbarns 1985). The mean percentage of daylight hours with bright sunshine is the highest in Canada (50%) or 2200 hrs/year (Fairbarns 1985). Total annual precipitation is between 260 to 280 mm, with two thirds of that falling as spring rains (Fairbarns 1985). Due to warm summer temperatures and a high average wind speed the rate of evaporation is high throughout the summer months (Adams *et al.* 2005; Knapton *et al.* 2005). Wind speeds of 70 to 90 km/hr and gusts over 130 km/hr are common.

At the northern limits of its range, Soapweed is found on well-drained coulee slopes that are generally eroded, dry and sparsely vegetated (Milner 1977; Fairbarns 1985; Csotonyi and Hurlburt 2000; Figure 8). They mostly occur on south-facing slopes. At Onefour, those slopes range in orientation from 34° (northeast) to 220° (south-southwest), and except for some sites sheltered by adjacent ridges, generally face away from prevailing southwest winds (Csotonyi and Hurlburt 2000). Soils tend to be alkaline and regosolic without shallow hardpan (Milner 1977; Fairbarns 1985).



Figure 8. Soapweed (*Yucca glauca*) in heavy flower. South-facing coulee slope is representative habitat of northern populations of Soapweed (Onefour, Alberta; June 1999). (Photo: D. Hurlburt.)

In Onefour, Soapweed is found on eroding kame slopes dominated by Sagebrush (*Artemisia cana*). Major grasses include Blue Grama (*Bouteloua gracilis*) and Muhly Grass (*Muhlenbergia cuspidata*), while Needle and Thread Grass (*Stipa comata*), June Grass (*Koeleria macrantha*) and Sand Grass (*Calamovilfa longifolia*) are locally common. Major forbs include Prickly Pear Cactus (*Opuntia polyacantha*), Pincushion Cactus (*Mamillaria vivipara*), Smooth Blue Beardtongue (*Penstemon nitidus*), and Broomweed (*Gutierrezia sarothrae*) (Wershler and Wallis 1986).

Habitat Trends

Most Soapweed habitat in Canada is naturally restricted to a few south-facing coulee slopes that are eroded and sparsely vegetated (Csotonyi and Hurlburt 2000). Although grazing is the predominant land use in the immediate vicinity of the yuccas, the habitat remains largely undisturbed and has not declined in availability.

At Onefour, a small proportion of Soapweed clones grow on the prairie uplands, presumably as a result of a prairie fire in the 1970s. The ability of Soapweed and yucca moths to spread beyond their current range may be dependent on ecological drivers that reduce competitive grasses during years of high fruiting. Historically, heavy grazing and wallowing by bison and fire may have performed that role (Samson and Knopf 1994; Samson *et al.* 2004). Fire in the mixed-grass prairie was estimated to occur every three to five years prior to European contact (Samson and Knopf 1994; Samson *et al.* 2004), but is only thought to have occurred once in Soapweed habitat at Onefour during the last 35 years.

Periodically, moths presumed to be Yucca Moths, have been found in garden specimens of yuccas. The prevalence of yucca in gardens has increased over the last decade (Hurlburt, D. pers. obs. 2012) and these manipulated patches may act as 'stepping stones' for yucca moths to expand their range. Given the low abundance of yuccas in such patches, it is unlikely that they would result in self-sustaining populations of yucca moths.

BIOLOGY

Life Cycle and Reproduction

Yucca Moth

Most adult Yucca Moths emerge from the soil from early June to mid-July (Hurlburt 2004). After emergence, they gather and mate within fresh Soapweed flowers (Riley 1892; Baker 1986; Addicott *et al.* 1990). Adult females actively gather pollen using their specialized maxillary tentacles and then usually fly to a fresh flower on another plant up to 50 m away (median 5 m; Marr *et al.* 2000). She then inserts her ovipositor through the carpal wall and lays an egg next to the developing ovules (Aker and Udovic 1981; Addicott and Tyre 1995). After ovipositing, she climbs to the tip of the style and actively stuffs the pollen in her tentacles into the stylar canal. Adult moths do not feed and die with 3-5 days of emergence (Kingsolver 1984).

Eggs hatch within 7-10 days and larvae immediately begin to feed on developing Soapweed seeds. After 50-60 days, usually late August or early September after a rain, fourth instar larvae chew their way out of the fruit, leaving behind an emergence hole or "window" (Csotonyi and Hurlburt 2000). Moth larvae then lower themselves to the ground via a silken thread (Riley 1892) and burrow 5-20 cm into the ground (Fuller 1990). After spinning a cocoon of silk and sand particles (Davis 1967), the larvae enter prepupal diapause (Riley 1875; Keeley *et al.* 1984). After a minimum diapause of 1 year, larvae pupate and adults emerge from the soil within several weeks, usually at the time of Soapweed flowering. At Onefour, it has been confirmed that prepupal diapause can last up to 4 years (D. Hurlburt, unpubl. data).

Non-pollinating Yucca Moth

Adult Non-pollinating Yucca Moths emerge from the soil in early July through September in Alberta (D. Hurlburt, unpubl. data), at which time they gather and mate in late-blooming Soapweed flowers or on Soapweed stalks and leaves (Snell and Addicott 2008). They oviposit into the seeds of early-stage Soapweed fruit (Addicott *et al.* 1990; Pellmyr *et al.* 1996) that are 2.5 to 4.0 cm in length (D. Hurlburt, unpubl. data) and on average, 12-15 days of age (James 1998). *Tegeticula corruptrix* lay 14-23 eggs (total per fruit) dispersed all over the fruit surface (Perry *et al.* 2004; Crabb and Pellmyr 2006). Pellmyr (1999) reports that a small droplet of sap exudes from each oviposition site, but this does not appear to occur in Alberta.

As with Yucca Moths, eggs hatch with 7-10 days and developing larvae, which go through 4 instars, feed on Soapweed seeds. Five to 6 weeks after hatching, larvae emerge from the fruit, lower themselves to the ground and spin a cocoon just prior to entering prepupal diapause. There is anecdotal evidence of extended diapause in Non-pollinating Yucca Moth. From 1998 to 2006, when there were no fruit known to be produced at Pinhorn, live Non-pollinating Yucca Moth cocoons were sifted from the soil surrounding Soapweed plants (D. Hurlburt unpubl. data). These cocoons had to be at least 3 years old, probably older.

Five-spotted Bogus Yucca Moth

Adult Five-spotted Bogus Yucca Moths begin to emerge about a week before Soapweed begins to flower, often congregating on leaves at the beginning of the emergence season and then residing within Soapweed flowers as the season proceeds. In the northern part of the species' range, adult emergence is from early June to mid-July (COSEWIC 2006a). In the evening, adults mate within yucca flowers and females then leave to oviposit on the flowering stalk. Eggs are deposited one at a time about 1-2 mm under the stalk surface (Davis 1967). On occasion, eggs are also laid in flower pedicels. A noticeable scar results at each oviposition site, allowing the presence of Five-spotted Bogus Yucca Moths to be easily detected in the field.

The eggs hatch about 9 days post-oviposition (Davis 1967). The larvae burrow deeper into the flowering stalk and begin to feed on stem tissue. After going through 3 moults within 30 days (Riley 1892), they spin a cocoon of silk and enter a state of prepupal diapause with the stalk.

In the spring, just prior to flowering, pupation occurs over approximately one week (Davis 1967). Adults emerge through holes in the stalk created during the pupal stage (Davis 1967). Most adults emerge within a year; however, it is expected that extended diapause in excess of 30 years may occur in some individuals (Powell 2001; see next section).

Physiology and Adaptability

Yucca Moth, Non-pollinating Yucca Moth, and Five-spotted Bogus Yucca Moth larvae exhibit diapause. Yucca Moth and Non-pollinating Yucca Moth overwinter as larvae in cocoons 5-20 cm below the soil surface (Fuller 1990). Five-spotted Bogus Yucca Moth overwinters as larvae in the flowering stalks of Soapweed.

All 3 species are thought to have some individuals that enter prolonged diapause for more than one year. The longest insect dormancy on record is that from a closely related species, *Prodoxus y-inversus*, where under laboratory conditions adult moths emerged after 30 years of diapause (Powell 2001). Fuller (1990) demonstrated that Yucca Moths can prolong diapause for at least 4 years, but only 9% of larvae in diapause were alive after 3 years and about 50% died in their cocoons each winter. This ability was confirmed at Onefour where moths emerged after 3 years; however, over 50% of larvae failed to pupate, and of those that pupated, half died in the cocoon (D. Hurlburt, unpubl. data).

The ability of some individuals in a population to extend diapause may be a bet-hedging strategy that ensures that some moths emerge during favourable conditions. This is likely a crucial adaptation in northern edge of range populations of yucca moths, where Soapweed exhibits highly variable flowering and reproductive success among years.

Dispersal and Migration

There is little known about dispersal or migration in the three yucca moths. In previous COSEWIC assessments, we have assumed that they are unlikely to fly over great distances. All three species of moths only live as adults for a few days and are weak flyers that do not directly fly from one yucca plant to another, i.e. their flight is random rather than deliberately directional (Kerley *et al.* 1993; Marr *et al.* 2000; COSEWIC 2006a, b). Genetic evidence, however, suggests that yucca moths (*Prodoxus desipiens* and *T. yuccasella*) have the ability to travel long distances as supported by their spread onto horticultural yuccas in the eastern United States; however, the frequency of these long-distance movements is sufficiently low to allow for some genetic divergence (Althoff and Pellmyr 2002; Leebens-Mack and Pellmyr 2004).

It is unknown if yucca moths can indirectly disperse on storm fronts or in high winds; however, in 2007, a number of *Yucca* plants in southern Alberta (i.e., Lethbridge, Magrath, Olds) gardens produced fruit and *Tegeticula* spp. larvae were reported for the first and only time. Similar occurrences in transplanted native plants were reported in the 1970s and 1980s in the Lethbridge area. These observations suggest that weather systems likely play a periodic role in either the dispersal of adult moths or as triggers in moth emergence. However, anthropogenic transportation of moths via pupa within the soil of transplanted plants cannot be ruled out.

Interspecific Interactions

A crucial element in the survival of the Yucca Moth is the survival and sexual reproduction of its host plant, the Soapweed (*Yucca glauca*). The Yucca Moth and the Soapweed have an obligate mutualistic relationship (Addicott 1995), where both species realize an increase in fitness from the association. The Yucca Moth is the sole pollinator of the Soapweed, which provides oviposition sites for adults and seeds as food for developing Yucca Moth larvae.

In addition to the Soapweed's obligate relationship with the Yucca Moth, the plant is also the sole host of the Non-pollinating Yucca Moth and the Five-spotted Bogus Yucca Moth. The Non-pollinating Yucca Moth is a seed predator and lays its eggs in early-stage Soapweed fruit. Its developing larvae eat a proportion of developing seeds, alongside of Yucca Moth larvae (COSEWIC 2006b). The second species, the Five-spotted Bogus Yucca Moth, a stem borer, lays its eggs in Soapweed inflorescences (COSEWIC 2006a). Neither of these species provides any known benefit to the Soapweed; however, their survival greatly depends upon the mutualism.

Soapweed with fruit are often inhabited by aphids, which are tended by several species of ants. This facultative mutualistic relationship between ants and aphids, which is dependent on the obligate mutualism between the Soapweed and Yucca Moth, has some interesting implications for its associates. Soapweed inhabited by ants experienced a 60% increase in the number of viable seeds produced per fruit, because ants reduced ovipositing by Non-pollinating Yucca Moths, whose larvae eat yucca seeds, but provide no beneficial services to the plant. Ants were also less likely to inflict damage on the yucca when aphids were present (Perry *et al.* 2004; Snell and Addicott 2008b; also see **THREATS AND LIMITING FACTORS**).

In Alberta and northern Montana, the survival of Five-spotted Bogus Yucca Moth larvae is dependent upon the presence of Soapweed fruit (which results from the mutualism between Soapweed and the Yucca Moth) and the presence of aphids feeding on the sap associated with the stalk. Five-spotted Bogus Yucca Moth larvae only survive in the green portions of the Soapweed stalk, although their eggs are spread throughout. Soapweed stalks, however, only remain 'green' up to the highest position of fruit along the stalk, unless aphids are present when the stalks remain green for longer durations and are thought to enhance the survival of *Prodoxus* larvae (Snell and Addicott 2008a).

Kerley *et al.* (1993) proposed that a closely related species of yucca, *Y. elata*, supported over 70 species of arthropods. Soapweed at Onefour has also been observed to provide food to birds (which strip larvae from inflorescences), Mule Deer (*Odocoileus hemionus*), White-tailed Deer (*Odocoileus virginianus*), Pronghorn Antelope (*Antilocapra americana*), Elk (*Cervus canadensis*) and Nuttall's Cottontail (*Sylvilagus nuttallii*); and provide shelter to Prairie Rattlesnake (*Crotalus viridis*), Bull Snake (*Pituophis catenifer*) and the Greater Short-horned Lizard (Hurlburt 2007). Mule Deer and Pronghorn have been observed to feed extensively on Soapweed stalks, flowers and fruits (see **THREATS AND LIMITING FACTORS**).

The larvae of Five-spotted Bogus Yucca Moths are parasitized by 3 species of Hymenoptera (Davis 1967): Eurytomidae: *Eudecatoma flammineiventris* (Girault); Ichneumonidae: *Calliephialtes notandus* (Cresson); and Braconidae: *Heterospilus prodoxi* (Riley). In the Onefour population, parasitism rates were low in 2002-03 (Snell 2004). Assuming that any unidentified larvae were parasitoids, then only 17 out of 1,829 Five-spotted Bogus Yucca Moth larvae were parasitized in 2002. There was no evidence of parasitism in 2003 (COSEWIC 2006a).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

No data are available on population size and trends for Yucca Moth, Non-pollinating Yucca Moth, or Five-spotted Bogus Yucca Moth; however, there are several indices from which population health can be inferred. Available data have been gathered using a range of methodologies in association with several research projects and/or monitoring projects since 1998.

Yucca Moth

A complete census of larval Yucca Moth recruits was conducted in 1998 by counting emergence holes in every Soapweed fruit at the Onefour and Pinhorn sites (Note: there were no fruit at Pinhorn; Csotonyi and Hurlburt 2000; COSEWIC 2002). From 1999-2003 and in 2007, moth abundance was assessed at Onefour by 1) moth counts in fresh flowers, 2) oviposition marks per fruit, 3) larvae per fruit and 4) fruit per inflorescence or clone (Hurlburt 2004; Hurlburt 2007). During Soapweed flowering in 1999-2003, D. Hurlburt counted all Yucca Moth in approximately 100 flowers across the Onefour site several times per week. Moths were assessed in a similar way, albeit for a shorter duration, during a week-long site visit in 2007 (Hurlburt 2007). A subset of individually marked clones and inflorescences were followed from 1999 to 2011 to determine fruit set. Annually, 30 to 200 mature Soapweed fruit were dissected to determine ovipositions per fruit and larvae per fruit.

Since the establishment of deer exclosures at Pinhorn in 2008, protected Soapweed clones have been monitored in the fall for fruit set per clone and inflorescence, and for the number of emergence holes per dehiscent fruit. It is possible that a small proportion of emergence holes at Pinhorn could be attributed to Non-pollinating Yucca Moth, but their presence at the site has not been observed since 1998 when a single specimen was observed flying.

Non-pollinating Yucca Moth

Approximately, 30 to 200 yucca fruit per population per year (1999-2003) were dissected after maturation to estimate Non-pollinating Yucca Moth abundance. The number of Non-pollinating Yucca Moth oviposition marks per fruit and the number of larvae per fruit were used as indices of moth activity and recruitment, respectively. Where possible (1999-2003, 2007), density of Non-pollinating Yucca Moths was assessed by counting the number of adult moths in fresh flowers; however, because of their late emergence, they often do not have access to Soapweed flowers in which to hide.

Five-spotted Bogus Yucca Moth

In 2002, Snell (2004; Snell and Addicot, 2008a, b) monitored 142 Soapweed clones 5 days per week during the flowering/fruitlet season at Onefour. During surveys, each open flower was examined for the presence/absence of Five-spotted Bogus Yucca Moth. The abundance of moths in each flower was not recorded (COSEWIC 2006a). The proportion of occupied flowers was used as an indirect metric of abundance. In 2003, the number of ovipositions per inflorescence and the number of larvae per inflorescence was determined for 16 clones at Onefour to estimate egg survivorship (COSEWIC 2006a; Snell 2004; Snell and Addicot 2008a,b). In addition, emergence holes in stalks were counted in 149 old inflorescences greater than 1 year of age.

During Soapweed flowering in 1999-2003, D. Hurlburt counted all 3 moth species in approximately 100 flowers across the Onefour site several times per week. Moths were assessed in a similar way, albeit for a shorter duration, during a week-long site visit in 2007 (Hurlburt 2007).

Abundance

Yucca Moth

The determination of adult Yucca Moth abundance is not possible due to their small size, their short-lived nature, high intra-annual variability and the inability to detect them outside of yucca flowers. Total counts of other life history stages are more feasible, especially during years of low flowering or fruiting. In 1998, for example, there were a total of 255 Yucca Moth larvae recruited at Onefour based on emergence holes from fruit (Csotonyi and Hurlburt 2000; COSEWIC 2002). In subsequent years (e.g. 1999, 2006, 2010), 1000s to 10000s of larvae were produced at that site (Hurlburt 2004; Hurlburt 2007; Hurlburt 2011).

Indirect indices of Yucca Moth abundance, including fruit per clone or inflorescence, moths per flower, ovipositions per fruit, larvae per fruit and, emergence holes per fruit are provided in Table 1.

Table 1. Indices of Yucca Moth (*Tegeticula yuccasella*) population size in Alberta from 1998 to 2011. Values from COSEWIC (2002) unless otherwise noted. For Pinhorn, values from 2009 and 2010 are presented for those protected by exclosures (excl.) and for the entire population (all).

	Fruit/ inflorescence	Fruit/ clone	Moths/ flower	Ovipositions/ fruit	# Larvae/ fruit	Emergence holes/fruit
Onefour						
1998	2.034±0.279	—	—	—	—	4.397±0.350
1999	3.102±0.161	4.537±0.328 ^a	0.456±0.259	9.552±1.261	3.560±0.470	—
2000	0.322±0.156	0.354±0.172 ^a	0.563±0.259	18.317±2.075	5.920±0.508	—
2001	1.411±0.115	2.119±0.207 ^a	0.388±0.235	14.755±1.489	4.396±0.576	—
2002	2.316±0.196 ^a	3.294±0.316 ^a	0.311	17.122±0.892 ^b	8.110±0.600 ^b	—
2003	2.316±0.196 ^a	3.294±0.316 ^a	—	6.617±0.309 ^b	2.900±0.690 ^b	—
2007 ^c	1.931±0.172	2.647±0.434	0.198	12.148±0.802	4.321±0.665	—
2011 ^a	0.180±0.063	1.252	—	—	—	—
Pinhorn						
1998	0.000±0.000	0.000±0.000	—	—	No fruit	No fruit
1999	0.000±0.000	0.000±0.000	0.003±0.000	0.000±0.000	No fruit	No fruit
2000	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000	No fruit	No fruit
2001	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000	No fruit	No fruit
2002	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000	No fruit	No fruit
2003	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000	No fruit	No fruit
2004	—	0.012	—	—	—	—
2008	—	0.024	—	—	—	—
2009excl ^e	0.150 (153)	0.054 (122)	—	—	—	1.130
2009-all ^e	—	0.054 (unk)	—	—	—	1.130
2010excl ^e	0.461 (347)	1.176 (136)	—	—	—	0.225
2010-all ^e	—	0.378 (160)	—	—	—	0.225

	Fruit/ inflorescence	Fruit/ clone	Moths/ flower	Ovipositions/ fruit	# Larvae/ fruit	Emergence holes/fruit
2011excl	1.707±0.414 ^a	2.188±0.613 (32) ^a	0.000 ^a 1	---	---	1.805 ^a
2011-all ^a	0.546±0.147	0.168 (71)	0.0001	---	---	---

^aD. Hurlburt, unpubl. data; ^bHurlburt (2004); ^cHurlburt (2007), ^dForeman *et al.* (2006), ^eAlberta Fish and Wildlife, unpubl. data

From 1998 to 2003 inclusive, only 1 adult Yucca Moth was observed within flowers at Pinhorn. No Yucca Moth cocoons were found by sifting soil samples from Pinhorn in 2000, nor were any oviposition marks noted within flowers from 1999 to 2003 (Hurlburt, unpubl. data). With relatively few flowers that escaped herbivory and the absence of Soapweed fruit production, no larvae were produced during that period. In 2004, 3 clones produced a total of 5 fruit with a total of 6 Yucca Moth emergence holes (Foreman *et al.* 2006). In August 2007, a single old Soapweed fruit was observed at Pinhorn. The fruit was partially dehiscent and contained seed with Yucca Moth larval damage from feeding, although the number of larvae that emerged is unknown. The fruit was thought to have originated from 2006 (Johnson pers. comm. 2011).

In 2008, deer exclosures were constructed to protect about 25% of the Soapweed plant population at the Pinhorn site from herbivory. In 2008, about 10 clones produced fruit within the exclosures (Nicholson pers. comm. in Environment Canada 2011). Moth emergence for that year is unknown. In 2009, 23 fruit from 9 clones were produced with a total emergence of 35 moth larvae for the entire site (AB Fish and Wildlife, unpubl. data). In 2010, 160 fruit from 38 clones were produced with a total emergence of 36 moth larvae (AB Fish and Wildlife, unpubl. data). In 2011, 86 fruit were produced at the site; all but 9 were within the exclosures (Hurlburt 2011; AB Fish and Wildlife, unpubl. data). One fruit from outside the exclosures had been torn off the yucca stalk and was lying on the ground (Hurlburt 2011). One hundred thirty-nine moth larvae emerged from 77 fruit within exclosures in 2011 (AB Fish and Wildlife, unpubl. data). No emergence was reported for unprotected clones in 2011.

Indirect indices of Yucca Moth abundance for Pinhorn indicate that Yucca Moths are present but that their abundance remains significantly lower than that at Onefour (Table 1). Most of the recent improvement in numbers can be attributed to a reduction in herbivory within exclosures. It is unclear whether current abundance is sufficient to sustain the population or the mutualism at Pinhorn given the high mortality of Yucca Moth larvae (see **Physiology and Adaptability**).

¹ Flowers were only surveyed for moths 1 day late in the flowering season.

Non-pollinating Yucca Moth

Non-pollinating Yucca Moth ovipositions per fruit ranged from 0.071 (2007) to 13.939 ± 0.875 (2002) at Onefour (Table 2). These values are within the range of those in the closest Montana population (Table 2) and from elsewhere in the species' range (COSEWIC 2006b). Larvae per fruit ranged from 0.033 ± 0.033 (2003) to 3.636 ± 0.254 (2002) and are comparable to those elsewhere (Table 2; COSEWIC 2006b). From 1999 to 2007, from 5% to 50% of fruit were infected with Non-pollinating Yucca Moth larvae. In 2011, no Non-pollinating Yucca Moth adults were observed in open flowers ($n=3$) at the tail end of the flowering season (Hurlburt, unpubl. data).

Table 2. Variation in vital rates for Non-pollinating Yucca Moth (*Tegeticula corruptrix*) among years and sites. Vital rates for other more southerly populations are in COSEWIC (2006b).

Site	Year	Ovipositions/fruit	Larvae/fruit	Proportion of fruit infected	Survival rate	Source
Onefour, AB	1999	5.400 ± 1.443	1.560 ± 0.451	—	0.289	Hurlburt, unpubl.
	2000	7.846 ± 5.329	0.692 ± 0.328	0.385	0.088	Hurlburt, unpubl.
	2001	2.350 ± 1.091	0.100 ± 0.069	0.100	0.042	Hurlburt, unpubl.
	2002	3.648 ± 5.376	0.110 ± 0.379	—	0.030	Hurlburt, unpubl.
	2002	13.939 ± 0.875	3.636 ± 0.254	—	0.261	Snell 2004
	2003	1.000 ± 0.235	0.033 ± 0.033	0.500	0.033	Hurlburt & Smith, unpubl.
	2007	0.071	0.036	0.050	—	Hurlburt(2007)
Fort Belknap, MT	2001	15.211 ± 22.233	0.947 ± 1.810	—	0.062	Hurlburt, unpubl.
	2002	17.726 ± 23.004	4.569 ± 6.061	—	0.358	Hurlburt, unpubl.
	2003	4.467 ± 0.090	0.200 ± 0.088	0.733	0.045	Hurlburt & Smith, unpubl.
Loma, MT	1999	2.789 ± 1.502	1.053 ± 0.492	0.211	0.378	Hurlburt, unpubl.
	2000	28.000 ± 24.458	0.273 ± 0.467	—	0.010	Hurlburt, unpubl.
	2001	1.200 ± 2.397	0.050 ± 0.224	—	0.042	Hurlburt, unpubl.
	2002	14.167 ± 14.049	0.500 ± 1.225	—	0.035	Hurlburt, unpubl.
	2002	0.534 ± 0.206	0.125 ± 0.084	—	0.234	Snell 2004
Decision Pt., MT	2002	8.933 ± 12.753	0.067 ± 0.258	—	0.008	Hurlburt, unpubl.
Fort Benton, MT	2000	0.384 ± 0.768	0.231 ± 0.599	—	0.602	Hurlburt, unpubl.
	2001	4.250 ± 7.615	0.300 ± 0.657	—	0.071	Hurlburt, unpubl.
	2002	0.171 ± 1.014	0.000 ± 0.000	0.000	0.000	Hurlburt, unpubl.
	2003	8.182 ± 2.064	0.227 ± 0.066	—	0.028	Snell 2004
Fort Benton 2, MT	2000	1.5 to 9	—	—	—	Perry 2001

A single live adult Non-pollinating Yucca Moth was captured in flight at Pinhorn in August 1998 (Csotonyi and Hurlburt 2000) and several cocoons with larvae in prepupal diapause were sifted from the soil in 2000 (Hurlburt, unpubl. data). There have been no observations of the species at Pinhorn since 2000, although it is expected that it persists in very low numbers.

Five-spotted Bogus Yucca Moth

During a sampling session in late June-mid July 2002 (COSEWIC 2006a), 5.97% of Soapweed flowers at Onefour were occupied by at least one adult Five-spotted Bogus Yucca Moth. A second survey from early June through August of that same year found a density of 0.310 ± 0.023 moths per flower (Table 3). Densities in 2007 and 2011 were 1.086 and 0.500 respectively (Table 3; Hurlburt, unpubl. data). In 2011, over 92% of Soapweed inflorescences were visited by the Five-spotted Bogus Yucca Moth at Onefour (Hurlburt, unpubl. data).

Table 3. Population and life history data for the Five-spotted Bogus Yucca Moth (*Prodoxus quinquepunctellus*) in Onefour, AB. Values from northern Montana populations are provided for comparison. Numbers shown are mean values + standard error.

	n stalks	Ovipositions per stalk	Larvae per stalk	Survivorship	Density per flower
Onefour, AB					
2002	—	—	15.765 ± 1.637	—	0.310 ± 0.023^2
2003	16	651.937 ± 130.452	27.437 ± 8.200	0.040 ± 0.090	—
2007	—	—	—	—	1.086^3
2011	—	—	—	—	0.500^4
Pinhorn, AB					
2004	—	0.000 ± 0.000	—	—	—
Loma, MT					
2002	—	—	23.667 ± 4.465	—	—
2003	68	273.691 ± 25.419	18.397 ± 3.519	0.053 ± 0.010	—
Ft Benton, MT					
2003	38	300.632 ± 32.458	41.868 ± 7.500	0.122 ± 0.016	—

² Hurlburt, unpublished data

³ Hurlburt (2007)

⁴ Hurlburt, unpublished data; only 6 flowers were sampled at the tail end of the flowering season

In 2002, at Onefour, Soapweed stalks had 2.301 ± 0.896 emergence holes per inflorescence, although emergence of Five-spotted Bogus Yucca Moth was not yet complete (COSEWIC 2006a). Stalks without fruit only had 1.91 ± 0.68 emergence holes whereas those with at least one fruit had 9.72 ± 2.36 (Snell 2004). Stalks that flowered prior to 2002 had 29.36 ± 6.437 emergence holes (COSEWIC 2006a). Dissection of stalks at Onefour in 2002 and 2003 revealed between 0 and 120 emergence holes per stalk (Snell 2004) with averages ranging from 15.765 ± 1.637 and 27.437 ± 8.200 (Table 3). Averages of emergence holes per stalk at Onefour were similar to those from other northern populations of Soapweed in Montana (Table 3; COSEWIC 2006a). R. Snell in COSEWIC (2006a) estimates the range of abundance of larvae among years to be 5,376 to 243,600.

Prior to 2011, the Five-spotted Bogus Yucca Moth was not known from the Pinhorn site, although Foreman (2006) indicated that there might have been some old oviposition scars on old Soapweed stalks. In August 2011, 50.78% of Soapweed inflorescences in exclosures had oviposition scars (Hurlburt, unpubl. data). This rate was significantly lower than that at Onefour. Seventy-five fresh flowers were examined at Pinhorn in 2011 and no moths were observed, although it was late in the flowering season (Hurlburt, unpubl. data).

Fluctuations and Trends

Fluctuations in Soapweed flowering, abundance of Yucca Moths, fruit production, levels of herbivory and the degree of mutualistic benefit realized (through viable seed production) is well documented in *Yucca* spp. and Yucca Moth populations across their ranges (Aker 1982; Addicott 1998; Hurlburt 2004). These fluctuations are thought to be even greater at the northern edge of the range (Hurlburt 2004), and have implications for detecting population trends over relatively short durations of time. The Alberta population of Soapweed and yucca moths has only been monitored on a regular basis since 1998; without longer-term data or sufficient population information for projection modelling, it is unknown if populations of yucca moths are stable, increasing or decreasing. It is possible, however, that small, isolated populations may be more susceptible to stochastic variation and decline than large populations in the centre of the range (COSEWIC 2002) and collapse of small populations for genetic reasons is well known in Lepidoptera (Saccheri *et al.* 1998).

Yucca Moth

Total Yucca Moth abundance at Onefour varies by up to 40-fold among years (see **Abundance**). Despite that high variability in abundance, moth densities in flowers and fruit only vary 2- to 4-fold among years (Table 1). There is no indication of a decline in Yucca Moth abundance since 1998 and available indices are consistent in variability with other populations at the northern edge of range.

At Pinhorn, there was a decline in Yucca Moth abundance from 1975 (last year of known fruit production) to 2003, based on the lack of fruit production from 1997 to 2003 (COSEWIC 2002). Since 2003, moth abundance increased slightly in 2006, and then increased to a greater extent from 2008 to 2011 as a result of protection from deer exclosures (Table 1). Although the population has increased in recent years, indices of abundance are significantly lower than at Onefour and other areas of the range (Table 1), and it is unclear whether abundance is high enough to sustain the population over the long-term, especially given only 25% of the Soapweed population is protected from deer herbivory.

Although the number of mature Yucca Moths fluctuated up to 40 times among years, the population may not fit the IUCN definition of severe fluctuation. If Yucca Moth populations undergo extended prepupal diapause, they may not be as susceptible to stochastic events as some moths remain in cocoons within the soil. That said, we only know that Yucca Moths exhibit diapause for up to four years and only a small proportion of individuals survive that length of time. Additionally, Soapweed flowers independently vary in availability among years and may not be present for moth reproduction during some years of high moth emergence. Moth abundance in any particular year cannot readily be attributed to availability of Soapweed flowers.

Non-pollinating Yucca Moth

Indices of Non-pollinating Yucca Moth abundance varied almost 200-fold for ovipositions per fruit and over 100-fold for larvae per fruit among years (Table 2). Between 5 and 50% of fruit at the Onefour site was infected with Non-pollinating Yucca Moth larvae from 1999 to 2007 (Table 2). There were no apparent declines or increases in population abundance from 1999 to 2007, and indices were within the range of other populations in Montana (Table 2).

Five-spotted Bogus Yucca Moth

Relatively few data are available to detect population trends for Five-spotted Bogus Yucca Moth in Alberta; however, abundance appears to fluctuate widely among years (Table 3).

As with Yucca Moth, it is unclear whether populations of Non-pollinating Yucca Moth and Five-spotted Bogus Yucca Moth could be said to undergo severe fluctuation because their ability to undergo extended diapause is not fully understood. Both of these species, however, would be more susceptible to extirpation than the Yucca Moth because their reproductive success is tied to production of Soapweed fruit.

Rescue Effect

Although these 3 species of yucca moths are common in *Yucca* spp. populations in the United States, the probability of them recolonizing sites in Canada is thought to be low. Yucca moths are short-lived, weak flyers and most of the intervening landscape between the Canadian sites and those in Montana is inhospitable (COSEWIC 2002; 2006a; 2006b). Yucca Moths are not known to travel long distances (Kerley *et al.* 1993; Marr *et al.* 2000; Pellmyr pers. comm. but see Althoff and Pellmyr 2002; Leebens-Mack and Pellmyr 2004); however, there is some anecdotal evidence in Alberta that suggests that periodically moths may be able to move long distances and temporarily occupy moth-depauperate *Yucca* populations. In addition, there are unsubstantiated reports of yucca moth larvae in fruit in gardens in southern Ontario (Hurlburt pers. comm. 2013), although native populations of *Yucca* spp. do not exist there so these yucca moths should be considered as 'manipulated' for COSEWIC purposes.

There are records of yucca moths (species unconfirmed) pollinating both native transplanted stock and horticultural specimens in gardens and producing fruit with *Tegeticula* larvae. There are incidents of this occurring on single occasions in the 1970s (Dormaar pers. comm. 1999), 1980s (Johnson pers. comm. 2011) and again in 2007 (Johnson pers. comm. 2011; Cunningham pers. comm. 2011, Harris pers. comm. 2011; Fry pers. comm. 2007; Pohl *et al.* 2005) in Lethbridge, Magrath and Olds, AB. There are no reported records of repeat fruiting in any of these gardens, so moth larvae may not be able to persist in these more northerly locations, or their abundance is too low to ensure survival to subsequent years.

THREATS AND LIMITING FACTORS

There are a number of natural and anthropogenic factors that may limit the distribution and abundance of Soapweed and therefore also affect its associated Yucca Moth, Non-pollinating Yucca Moth and Five-spotted Bogus Yucca Moth in Canada. Soapweed relies primarily on asexual reproduction in its Canadian range, but lack of sexual reproduction may impact the long-term persistence of Soapweed, in addition to having effects on the three moth species listed above. As a result, factors that affect sexual reproduction of Soapweed are important to consider even if they do not appear to be critical to short-term persistence.

Natural Limiting Factors

Obligate Mutualistic Relationship

Although Soapweed populations can persist through asexual propagation, the absence of sexual reproduction may limit population growth and range expansion and restrict the ability of a species to adapt to changing conditions. Sexual reproduction in Soapweed requires the presence of its highly co-evolved pollinator, the Yucca Moth.

Small or newly established populations of Soapweed may not have adequate numbers of Yucca Moths to sustain successful sexual reproduction. Yucca moths are short-lived, particularly weak flyers, and therefore are unlikely to disperse long distances (Kerley *et al.* 1993; Marr *et al.* 2000). Further, there is evidence to suggest that small populations of Soapweed may not contain enough flowering plants to sustain permanent populations of Yucca Moths (Dodd 1989; Dodd & Linhart 1994; COSEWIC 2002).

Contrary to the host plant, all three yucca moth species require sexual reproduction to occur in the Soapweed in order to reproduce and allow yucca moth populations to persist. To some degree, extended prepupal diapause in yucca moths is thought to allow moth populations to persist in times of limited host plant sexual reproduction or flowering; however, the exact duration of diapause is unknown and the extent of host plant reproductive failure moths can withstand is unknown. Repeated reproductive failure of the plant over a 25-30 year period (due to wild ungulate herbivory) is thought to have led to declining Yucca Moth populations on the Pinhorn Grazing Reserve.

Insect Herbivory

The mutualism between Soapweed and the Yucca Moth is likely to be negatively impacted by the presence of the Non-pollinating Yucca Moth (Perry 2001; D. Hurlburt, unpubl. data), whose larvae consume Soapweed seeds (Addicott 1996) and compete with Yucca Moth larvae for food (James 1998). At Onefour, Non-pollinating Yucca Moth larvae are abundant in some years and can consume up to 40% of seeds (COSEWIC 2002; COSEWIC 2006b). The presence of ants on Soapweed reduces the impact of Non-pollinating Yucca Moth (see **Interspecific Interactions**), resulting in indirect benefits to fruit set of Soapweed and to the Yucca Moth (Snell 2008b).

Ants can, however, significantly reduce the availability of Soapweed flowers in which moths can oviposit, and may kill or harass adult moths in flowers patrolled by the ants (Perry 2001). Ants reduce the availability of Soapweed flowers by chewing on buds and subsequently causing the premature abscission of those buds. Some plants at Onefour lose up to 90% of their buds through ant damage (COSEWIC 2002). Ants are also attracted to Soapweed plants by aphids, but ants tend to be present on Soapweed even in the absence of aphids.

Extreme Weather Events

The Dry Mixedgrass prairie where the Alberta populations occur, is characterized by extreme weather events, including high temperatures, high or low levels of rainfall and high winds. Days of heavy rain or high winds are not uncommon and can have considerable impacts on the reproductive success of Soapweed within a given year.

Intense wind gusts over 100 km/hr can cause significant loss of Soapweed flowers and buds, reducing availability of Soapweed flowers to moths for pollination or destroying larvae in early stage fruit through premature removal of fruit from the stalk (COSEWIC 2002). In 1999, over half of the flowers and developing fruits at the Onefour site, and 100% of uneaten flowers at the Pinhorn site, were destroyed on a particularly windy day (COSEWIC 2002). Individual plants located at the tops of coulee slopes or on the prairie flats were particularly susceptible. Yucca Moth may be affected further during such adverse conditions because the wind makes it more difficult for moths to fly among inflorescences to collect pollen or to pollinate (Cruden *et al.* 1976, Aker 1982, Hurlburt 2004); moths have been observed to remain in Soapweed flowers during extreme periods of wind (COSEWIC 2002, Hurlburt 2004).

Anthropogenic Threats

A number of anthropogenic threats have been identified with the potential to threaten persistence and/or sexual reproduction of Soapweed and yucca moths in Canada. At present, these are mostly considered potential threats as some occurred at the time of the last assessment, but have since been mitigated. Few are known to have ongoing negative impacts on known populations in 2013.

Habitat Alteration and Degradation

Lack of Disturbance

A lack of natural disturbance may limit the availability of open patches that favour the establishment of new Soapweed plants. Historically, heavy grazing and wallowing by bison, as well as periodic fires, may have helped reduce the abundance and density of competitive grasses (Samson and Knopf 1994; Samson *et al.* 2004). Fire in the mixed-grass prairie was estimated to occur every three to five years prior to European contact (Samson and Knopf 1994; Samson *et al.* 2004), but is thought to have occurred only once in Soapweed habitat at Onefour during the last 35 years.

Wild Ungulate Herbivory

Herbivory by Pronghorn and Mule Deer on Soapweed inflorescences, flowers and fruit has a negative impact on Soapweed sexual reproduction and the recruitment of yucca moths in some years and sites (Hurlburt 2004). Pronghorn eat individual Soapweed flowers, whereas Mule Deer most often eat large portions of the entire flowering stalk. Fruit are also susceptible to consumption by both Pronghorn and Mule deer. Herbivory can directly destroy adult moths within flowers, eggs in flowers or early stage fruit, and larvae within older fruit.

When the number of available inflorescences is low, the impact of herbivory can be severe (affecting 80-100% of flowers). A small number of mule deer (2 or 3) can consume hundreds of Soapweed stalks in a single evening. In years of high flowering at Onefour, the impact of herbivory has been low (less than 1% of flowers) (COSEWIC 2002). At Pinhorn, the numbers of clones is smaller and mule deer almost always eat most or all available inflorescences (Csotonyi and Hurlburt 2000, Hurlburt 2001, COSEWIC 2002, Hurlburt 2004). Prior to the construction of exclosures, sexual reproduction and yucca moth populations were severely impacted by wild ungulate herbivory.

Over the short term, the impact of herbivory on population projections for Soapweed in Canada is expected to be low because individuals are long-lived and populations rely mostly on asexual reproduction, as shown in the population projection models presented in Hurlburt (2004). The population projection models incorporated patterns of flowering and intensity of herbivory into population projections for Soapweed based on data for the Onefour population.

At Pinhorn, failure of Soapweed to set fruit between 1997 and 2002 was attributed to repeated, intense herbivory of inflorescences, which resulted in the apparent loss of Yucca Moth from this site (COSEWIC 2002). Prior to 1997, the last known occurrence of fruiting was 1975 (Csotonyi and Hurlburt 2000). Since the Yucca Moth assessment in 2002, there have been some improvements for Soapweed and Yucca Moth at Pinhorn. In 2004 and in 2007, several fruits with Yucca Moth emergence holes and/or larval damage to seeds were located at the site (Foreman *et al.* 2006; Environment Canada 2011). In 2004, 3 clones produced a total of 5 fruits with a total of 6 Yucca Moth emergence holes (Foreman *et al.* 2006). In August 2007, a single old Soapweed fruit was observed at Pinhorn. The fruit, thought to have originated from 2006 (Johnson pers. comm. 2011), contained seeds with Yucca Moth larval damage from feeding.

In 2008, Alberta Fish and Wildlife constructed deer exclosures to protect a portion of the Soapweed plants at the Pinhorn site. Soapweed fruit set and observations of yucca moths have increased steadily within the exclosures since 2008. By 2010, 160 fruits were produced by 38 clones, and a total emergence of 36 moths (AB Fish and Wildlife, unpublished data). In 2011, 71 fruits were produced at the site; all but 1 were within the exclosures. At the time of sampling in 2011, moth larvae had not yet emerged from the fruits. These results indicate the potential to recover fruit set and restore a healthy population of Yucca Moth to Pinhorn with ongoing protection from herbivores. However, it is not clear whether Yucca Moth abundance at the site is adequate for long-term survival of the moth and the mutualism, as fruiting and moth emergence remain low compared to elsewhere (Hurlburt 2004, Hurlburt 2011).

Grazing by Cattle

In both Alberta sites, Soapweed and their moths coexist with cattle grazing. Most Soapweed occur on steep, rocky slopes that are not preferred by cattle, but cattle have been known to occasionally consume flowering stalks of Soapweed along the tops of coulee slopes (COSEWIC 2002). Other than using some travel corridors along select slopes to reach the coulee bottom for shelter and water, cattle generally make little use of the steep slopes where most Soapweed occurs.

Some Soapweed at the tops of slopes and on prairie in Onefour have been susceptible to cattle grazing during drought, such as the one that occurred in 2001. Typically, the Onefour Research Substation has not pastured cattle in the area of the Soapweed during flowering and fruiting; however, during periods of drought, such as in 2001, feed for cattle can be in short supply and there was need to use the pasture (COSEWIC 2002). Grazing has not been a problem in Pinhorn since 1998 (no information exists prior to then), even though cattle have access to the area during the flowering and fruiting season. There are few observations of cow manure within the Soapweed patch. That said, Mule Deer usually consume all of the stalks shortly after the initiation of flowering (Hurlburt, pers. obs.), so there may be little incentive for cattle to forage for Soapweed at this site. Destruction of *Yucca* inflorescences by grazing cattle is common in the United States, and it is plausible that grazing could become a substantial threat in Alberta should the Soapweed expand its habitat (COSEWIC 2002).

Agricultural Crop Production

Most areas inhabited by Soapweed are not ideal for cultivation and are in no immediate threat of such activity. It is possible that cropland conversion and associated activities, like pesticide application, could take place in the future, especially on the prairie upland areas at Onefour, as those activities do occur immediately across the Lost River coulee in Montana. However, existing protections and land ownership make this unlikely (see **Protection, Status and Ranks**).

Although herbicides have only been used to spot-kill individual weedy plants near the Onefour Soapweed site, widespread use of herbicides and insecticides could cause widespread plant and moth mortality and reduce reproductive success. In Montana, Soapweed plants along roadsides have fewer ovipositions and produce fewer fruits in areas sprayed for weed control, which could impact plants, especially at the Rockglen site in the future.

Oil and Gas Development

Both the Onefour and Pinhorn sites are on public land and could experience degradation of habitat through oil and gas activity (ASYMRT 2006). There has been no oil and gas development at Onefour, but there was some development and new road construction near the Pinhorn site around 2003. In 2009, protective notations were placed on quarter sections containing Soapweed at Pinhorn and Onefour for the purpose of protecting habitat for rare and endangered species. The notation prohibits surface deposition, but allows unimproved grazing. They expire in 2015 but are renewable. At Onefour, all oil and gas dispositions must obtain consent from the Minister of Community Development, given that the Soapweed occur within the boundaries of the Onefour Heritage Rangelands Natural Area (Environment Canada 2011).

Off-road Vehicle Use

Prior to 2003, Soapweed sites at Onefour and Pinhorn were well known and highly accessible by passenger vehicles, and the sites were regularly visited. Crushed plants had been observed at both locations. Since 2003, the impact of off-road vehicle use has noticeably declined (Hurlburt 2011) and these activities do not appear to be a major current threat.

Agriculture and Agri-Food Canada has imposed some conditions on access to the lands they manage at Onefour, partly as means to address concerns regarding liability and fire hazard. In 2011, Hurlburt (2011) observed considerable recovery of the vegetation along prairie trails and did not observe any sign of off-trail vehicle use. General access to the Pinhorn Grazing Reserve is more regulated than in past with restrictions on accessing pastures with cattle and using ungravelled trails.

Harvesting for Horticultural and Medicinal Uses

Prior to 2003, Soapweed plants were routinely dug up at Onefour and Pinhorn and transplanted to home gardens (COSEWIC 2000, 2002), but no such activity has been observed since that time (Hurlburt pers. obs.).

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

Yucca Moth, Non-pollinating Yucca Moth and Five-spotted Bogus Yucca Moth were assessed as Endangered by COSEWIC and are protected under Schedule 1 of SARA (COSEWIC 2002; COSEWIC 2006a; COSEWIC 2006b). Soapweed was originally assessed by COSEWIC in 1985 as Vulnerable (Fairbairns 1985) and as Threatened in 2000 (Csotonyi and Hurlburt 2000). In 2003, it was reassessed under new criteria when SARA was implemented and was designated as Threatened by COSEWIC and added to SARA Schedule 1.

In 2003, the Minister of Sustainable Resource Development approved the listing of Soapweed and Yucca Moth as 'Endangered' under Alberta's *Wildlife Act* based on recommendations from the Alberta Endangered Species Conservation Committee. At present, however, only Soapweed is listed in Alberta (ASYMRT 2006). All three moth species do, however benefit from the indirect protection afforded its host plant.

Alberta Sustainable Resource Development developed a Recovery Plan for Soapweed and Yucca Moth in Alberta (2006-2011) (ASYMRT 2006), and in 2011, Environment Canada prepared an addendum to that plan to make it into a SARA compliant recovery strategy (Environment Canada 2011). Environment Canada (2011) recommends the creation of a multi-species Action Plan that benefits all species that are dependent on Soapweed, including Yucca Moth, Non-pollinating Yucca Moth and Five-spotted Bogus Yucca Moth, and the as yet unassessed species, Strecker's Giant Skipper. An update to the Alberta Recovery Plan is currently under preparation.

Non-Legal Status and Ranks

Yucca Moth, Non-pollinating Yucca Moth and Five-spotted Bogus Yucca Moth are common in *Yucca* spp. populations throughout their ranges and are apparently secure globally (G4G5; NatureServe 2011). In Canada and Alberta, all 3 species are ranked critically imperiled (N1 and S1 respectively; NatureServe 2011). Yucca Moth, Non-pollinating Yucca Moth and Five-spotted Bogus Yucca Moth are all considered globally secure (G4G5) (NatureServe 2013).

Soapweed is common throughout most of its range and has been assessed as globally secure (G5; NatureServe 2011). In Canada, Soapweed has a conservation status of critically imperiled (N1) while in the United States it is considered secure (N5; NatureServe 2011). Soapweed is critically imperiled (S1) in Alberta and is considered to be introduced in Saskatchewan (SNA) (NatureServe 2011; Saskatchewan Conservation Data Centre 2011), although the accompanying COSEWIC Status Report is considering the Rockglen population of Soapweed as naturally occurring.

Habitat Protection and Ownership

Yucca Moth, Non-pollinating Yucca Moth and Five-spotted Bogus Yucca Moth exclusively use Soapweed as habitat. The Onefour population of Soapweed is on provincial land under lease to the federal government (considered to be federal lands) and is protected under SARA. The Onefour population also occurs within the Onefour Heritage Rangeland Natural Area designated by Alberta Community Development (Parks and Protected Areas Division), although relatively little public access occurs at the Onefour Soapweed population. Natural Areas protect sites of local significance and provide opportunities for low-impact recreation and nature appreciation activities. Land use in the Natural Area is regulated by the *Alberta Public Lands Act*.

The Pinhorn population occurs on provincial lands leased to the Pinhorn Grazing Association. This grazing reserve provides access to pasture for local ranchers, recreational opportunities for the public and access for resource extraction and development.

Critical habitat for Soapweed and Yucca Moth was described in the Soapweed and Yucca Moth Recovery Plan (ASYMRT 2006), and identified in the federal recovery strategy as 182 ha at the AAFC Onefour Research Substation and the 2.65 ha at the Pinhorn site (ASYMRT 2006, Environment Canada 2011).

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This updated status report is based upon previous COSEWIC status reports for Yucca Moth (COSEWIC 2002), Non-pollinating Yucca Moth (COSEWIC 2006b) and Five-spotted Bogus Yucca Moth (COSEWIC 2006a). Prior Soapweed assessments were prepared by Fairbairns (1985) and Csotonyi and Hurlburt (2000).

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INFORMATION SOURCES

- Adams, B.W., L. Poulin-Klein, D. Moisey and R.L. McNeil. 2005a. Range plant communities and range health assessment guidelines for the Dry Mixedgrass natural subregion of Alberta. Pub. No. T/040, Alberta Sustainable Resource Development, Rangeland Management Branch, Public Lands and Forests Division, Lethbridge, AB. 106 pp.
- Addicott, J.F., J. Bronstein, and F. Kjellberg. 1990. Evolution of mutualistic life-cycles: Yucca Moths and fig wasps. In: Gilbert, F. (ed.). Insect Life Cycles: Genetics, Evolution and Co-ordination. Springer, London pp. 143-161.
- Addicott, J.F. 1995. Ecology of mutualism. *Encycl. Environ. Biol.* 1:601-611.
- Addicott, J.F., and A.J. Tyre. 1995. Cheating in an obligate mutualism: how often do Yucca Moths benefit Yuccas? *Oikos* 72:382-394.
- Addicott, J.F. 1996. Cheaters in Yucca/Moth Mutualism. *Nature* 380:114-115.
- Addicott, J.F. 1998. Regulation of mutualism between yuccas and yucca moths: population level processes. *Oikos* 81:119-129.
- Aker, C.L. and D. Udovic. 1981. Oviposition and pollination behaviour of the Yucca Moth, *Tegeticula maculata* (Lepidoptera: Prodoxidae), and its relation to the reproductive biology of *Yucca whipplei* (Agavaceae). *Oecologia* 49:96-101.
- Aker, C.L. 1982. Spatial and temporal dispersion patterns of pollinators and their relationship to the flowering strategy of *Yucca whipplei*. *Oecologia* 54: 243-252.
- Alberta Soapweed and Yucca Moth Recovery Team (ASYMRT). 2006. Recovery plan for soapweed and yucca moth in Alberta 2006-2011. Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species at Risk Report No. 11. Edmonton, Alberta. 21 pp.
- Alberta Sustainable Resource Development. 2002. Status of the Yucca Moth (*Tegeticula yuccasella*) in Alberta. Alberta Sustainable Resource Development, Fish and Wildlife Division, and Alberta Conservation Association, Wildlife Status Report No. 44, Edmonton, AB. 21 pp.
- Althoff, D.M. and O. Pellmyr. 2002. Examining genetic structure in a bogus yucca moth: a sequential approach to phylogeography. *Evolution* 56:1632-1643.
- Althoff D.M., K.A. Segraves, and J.P. Sparks. 2004. Characterizing the interaction between the bogus yucca moths and yuccas: do bogus yucca moths impact yucca reproductive success? *Oecologia* 140: 321-327
- Anweiler, G.G. 2005. *Megathymus streckeri* in Roever, K. 2004 Season Summary. *News of the Lepidoterist's Society* 47 (S1): 17.

- Baker, H.G. 1986. Yuccas and Yucca Moths - a historical commentary. *Ann. Missouri Bot. Gard.* 73:556-564.
- Bradley, C., C. Wallis, and C. Wershler. 2006. Plant species at risk on AAFC Onefour, Alberta. Prepared for Agriculture and Agri-Food Canada, Regina, SK. vi + 107 pp.
- Coolidge, K.R. 1909. Preoccupied genera in Lepidoptera. *Entomological News* 20:112.
- Csotonyi, J. T., and D. Hurlburt. 2000. Update status report for Soapweed (*Yucca glauca*). Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. 11 pp.
- COSEWIC 2002. COSEWIC assessment and update status report on the yucca moth *Tegeticula yuccasella* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 24 pp.
- COSEWIC 2006a. COSEWIC assessment and status report on the Five-spotted Bogus Yucca Moth *Prodoxus quinquepunctellus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 31 pp.
- COSEWIC 2006b. COSEWIC assessment and status report on the Non-pollinating Yucca Moth *Tegeticula corruptrix* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 24 pp.
- Crabb, B.A. and O. Pellmyr. 2004. Defection by plants in the yucca-yucca moth association: a test of the cheater plant hypothesis for *Yucca treculeana*. *Oikos* 107: 321-328.
- Cruden, R.W., S. Kinsman, R.E.I. Stockhouse and Y.B. Linhart. 1976. Pollination, fecundity, and the distribution of moth-flowered plants. *Biotropica* 8:204-210.
- Cunningham, E.B. pers. comm. 2011. *Email correspondence to D. Hurlburt*. July 2011. Retired Biologist, Magrath, AB.
- Davis, D.R. 1967. A revision of the moths of the subfamily Prodoxinae. *U.S. Nat. Museum Bull.* 255:1-170.
- Dodd, R.J. 1989. Coevolutionary dynamics between *Yucca glauca* and *Tegeticula yuccasella* along an elevational transect in the Front Range of Colorado. M.A. thesis, University of Colorado, Boulder, CO. 77pp.
- Dodd, R.J., and Y.B. Linhart. 1994. Reproductive consequences of interactions between *Yucca glauca* (Agavaceae) and *Tegeticula yuccasella* (Lepidoptera) in Colorado. *Am. J. Bot.* 81:815-825.
- Dormaar, J. pers. comm. 1999. *Email correspondence to D. Hurlburt*. April 1999. Emeritus Research Scientist, Agriculture and Agri-Food Canada, Lethbridge, AB.
- Engelmann, G. 1872a. The flower of Yucca and its fertilization. *Bulletin of the Torrey Botanical Club* 3(7): 33.
- Engelmann, G. 1872b. Note. *Bulletin of the Torrey Botanical Club* 3(8): 37.
- Environment Canada. 2011. Recovery Strategy for the Soapweed (*Yucca glauca*) and Yucca Moth (*Tegeticula yuccasella*) in Canada. *Species at Risk Act Recovery Strategy Series*. Environment Canada, Ottawa. 15 pp + Appendix.

- Fairbarns, M.D. 1985. Status report on Soapweed *Yucca glauca*, a rare species in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. 10 pp.
- Foreman, K., J. Nicholson, L. Matthias, and J. Chandler. 2006. 2004 Pinhorn Grazing Reserve Soapweed population survey. Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species at Risk Report No. 111, Edmonton, Alberta. 9 pp.
- Fry, K. pers. comm. 2007. *Email correspondence to Greg Pohl*. August 2007. Entomologist, School of Environment, Olds College, Olds, AB.
- Fuller, O.S. 1990. Factors affecting the balance of co-operation and conflict between the Yucca Moth, *Tegeticula yuccasella* and its mutualist, *Yucca glauca*. - Ph.D. thesis, University of New Mexico, Albuquerque, NM. 91 pp.
- Groen, A.H. 2005. *Yucca glauca*. In: Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer).
- Harris, P. pers. comm. 2011. *Email correspondence to D. Hurlburt*. July 2011. Emeritus Research Scientist, Agriculture and Agri-Food Canada, Lethbridge, AB.
- Holtshausen, L., Chaves, A.V., Beauchemin, K.A., McGinn, S.M., McAllister, T.A., Cheeke, P.R., and Benchaar, C. 2009. Feeding saponin-containing *Yucca schidigera* and *Quillaja saponaria* to decrease enteric methane production in dairy cows. *Journal of Dairy Science* 92(6): 2809-2821.
- Hurlburt, D. 2001. Status of Soapweed (*Yucca glauca*) in Alberta. Alberta Environment, Fisheries and Wildlife Management Division, and Alberta Conservation Association, Wildlife Status Report No. 35, Edmonton, AB. 18 pp.
- Hurlburt, D. D. 2004. Persistence of the mutualism between Yuccas and Moths at the northern edge of range. Ph. D. thesis, University of Alberta, Edmonton, Alberta. 179 pp.
- Hurlburt, D.D. 2007. Yucca moth (*Tegeticula yuccasella*) population assessment and monitoring methodology at AAFC Onefour Research Substation, Alberta in 2007 – Final Report. Prepared for Agriculture and Agri-Food Canada, Regina, SK. 42 pp.
- Hurlburt, D. 2011. Field Verification Report on Soapweed (*Yucca glauca*) and Yucca Moths (*Tegeticula yuccasella*, *Tegeticula corruptrix*, *Prodoxus quinquepunctellus*) in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. 7 pp.
- Hurlburt, D. pers. comm. 2012. Soapweed and Yucca moth Biologist & Status Report Author, Annapolis Royal, N.S.
- James, M. L. 1998. Limits on the exploitation of the Yucca-Yucca Moth mutualism. M.Sc. thesis, University of Alberta, Edmonton, AB. 107pp.
- Johnson, D. pers. comm. 2011. *Email correspondence to D. Hurlburt*. July 2011. Professor, University of Lethbridge, Lethbridge, AB.

- Keeley, J.E., S.C. Keeley, C.C. Swift, and J. Lee. 1984. Seed predation due to the Yucca-moth symbiosis. *Am. Midl. Nat.* 112: 187-191.
- Kerley, G.I.H., Tiver, F. and W.G. Whitford. 1993. Herbivory of clonal populations: cattle browsing affects reproduction and population structure of *Yucca elata*. *Oecologia* 93:12-17.
- Kingsolver, R.W. 1984. Population biology of a mutualistic association: *Yucca glauca* and *Tegeticula yuccasella*. Ph.D. thesis, University of Kansas, Lawrence, KS. 130 pp.
- Knapton, R.W., G.L. Holroyd, and H.E. Trefry. 2005. Vertebrate Species at Risk at Onefour Research Sub-station, Alberta up to 2005. Canadian Wildlife Service Technical Report Series No. 446. Prairie and Northern Region. Edmonton, AB. V + 70 pp.
- Lesica, F., and F.W. Allendorf. 1995. When are peripheral populations valuable for conservation? *Conservation Biology* 9:753-760.
- Lomolino, M.V., and R. Channell. 1998. Range collapse, re-introductions, and biogeographic guidelines for conservation. *Conservation Biology* 12:481-484.
- Maher, R.V., G.W. Argus, L. Harms, and J.H. Hudson. 1979. The rare vascular plants of Saskatchewan. *Syllogeus* No. 20. National Museum of Canada, Ottawa, ON. 55 pp.
- Marr, D.L., J. Leebens-Mack, L. Elms and O. Pellmyr. 2000. Pollen dispersal in *Yucca filamentosa* (Agavaceae): The paradox of self-pollination behavior by *Tegeticula yuccasella* (Prodoxidae). *Am. J. Bot.* 87:670-677.
- McCleary, J.A. and K.A. Wagner. 1973. Comparative germination rates and early growth studies of the genus *Yucca*. *American Midland Naturalist* 90: 502-508.
- Milner, B.J. 1977. Habitat of *Yucca glauca* Nutt. in southern Alberta. M.Sc. thesis, University of Alberta, Edmonton, AB. 72 pp.
- Natural Regions Committee 2006. Natural Regions and Subregions of Alberta. Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. Pub. No. T/852.
- NatureServe. 2011. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available <http://www.natureserve.org/explorer>. (Accessed: October 21, 2011).
- Olson, P.L. 1976. A scenic resource and recreational analysis of the Milk River Canyon, Southeast Alberta. M.A. thesis, University of Calgary, Calgary, AB. 172 pp.
- Pellmyr, O. 1999. Systematic revision of the Yucca Moths in the *Tegeticula yuccasella* complex (Lepidoptera: Prodoxidae) north of Mexico. *Syst. Ent.* 24:243-271.
- Pellmyr, O. 2003. Yuccas, yucca moths and coevolution: a review. *Annals of Missouri Botanical Gardens* 90: 35-55.
- Pellmyr, O. and J. Leebens-Mack. 2001. Reversal of mutualism as a mechanism for adaptive radiation in Yucca Moths. *American Naturalist* 156:S62-S76.

- Pellmyr, O., J. Leebens-Mack & C.J. Huth. 1996. Non-mutualistic yucca moths and their evolutionary consequences. *Nature* 380:256-257
- Perry, J. 2001. Indirect mutualism: how ants affect the Yucca-Yucca Moth relationship. BSc (Honours) thesis, University of Alberta, Edmonton. 34 pp
- Perry, J. C.; Mondor, E. B.; Addicott, J. F. 2004. An indirect mutualism: ants deter seed predators from ovipositing in yucca fruit. *Canadian Journal of Zoology* 82: 823-827.
- Pohl, G.R., C.D. Bird, J-F. Landry and G.G. Anweiler. 2005. New records of Microlepidoptera in Alberta, Canada. *Journal of the Lepidopterists' Society* 59(2): 61-82.
- Pohl, G.R., G.G. Anweiler, B.C. Schmidt and N.G. Kondla. 2010. An annotated list of the Lepidoptera of Alberta, Canada. *ZooKeys* 38: 1-549.
- Powell, J.A. 1989. Synchronized, mass-emergences of a Yucca Moth, *Prodoxus Y-inversus* (Lepidoptera: Prodoxidae), after 16 and 17 years in diapause. *Oecologia* 81:490-493.
- Powell, J. A. 1992. Interrelationships of yuccas and yucca moths. *Trends in Ecol. & Evol.* 7(1):10-15.
- Powell, J.A. 2001. Longest insect dormancy: Yucca Moth larvae (Lepidoptera: Prodoxidae) metamorphose after 20, 25, and 30 years in diapause. *Ann. Entomol. Soc. Am.* 94:677-680.
- Riley, C.V. 1873. On the oviposition of the Yucca Moth. *Am. Nat.* 7: 619-623.
- Riley, C.V. 1892. The Yucca Moth and Yucca pollination. *Ann. Rep. Missouri Bot. Gard.* 3:99-158.
- Samson, F.B., and F.L. Knopf. 1994. Prairie conservation in North America, *BioScience* 44:418-421.
- Samson, F.B., F.L. Knopf, and W.R. Ostlie. 2004. Great Plains ecosystems: past, present and future. *Wildlife Society Bulletin* 32:6-15.
- Saunders, L. and R. Ernst. 1998. 1997 Rare Plant Report: City of Lethbridge, Lethbridge, AB. 12 pp.
- Saskatchewan Conservation Data Centre. October 2011. Saskatchewan Vascular Plant Species List. Regina, Saskatchewan. 161 pp.
<http://www.biodiversity.sk.ca/Docs/vasc.pdf> (Accessed 21 October 2011).
- Shapiro, J.M. and J.F. Addicott. 2003. Regulation of moth-yucca mutualisms: mortality of eggs in ovipositions-induced 'damage zones'. *Ecology Letters* 6: 440-447.
- Shapiro, J.M. and J.F. Addicott. 2004. Re-evaluating the role of selective abscission in moth / yucca mutualisms. *Oikos* 105: 449-460.
- Snell, R.S. 2004. Direct and indirect effect of ants on moth/yucca interactions: how additional species affect the costs/benefits in an obligate mutualism. M.Sc. thesis, University of Calgary, Calgary, Alberta.

- Snell, R.S. and Addicott, J.F. 2008a. Limiting the success of stem borers (*Prodoxus quinquepunctellus*) in Yuccas: indirect effects of ants, aphids and fruit position. *Ecological Entomology* 33(1):119-126.
- Snell, R.S. and J.F. Addicott. 2008b. Direct and indirect effects of ants on seed predation in moth/yucca mutualisms. *Ecoscience* 15(3): 305-314.
- Trelease, W. 1893. Further studies of yuccas and their pollination. Fourth Annual Report of the Missouri Botanical Gardens 4: 181-226.
- Tuttle, J.P. (ed.). 2005. Season Summary. *News of The Lepidopterists' Society* 47 (S1): 17.
- Wagner, D.L. and J.A. Powell. 1988. A new *Prodoxus* from *Yucca baccata*: first report of a leaf-mining prodoxine (Lepidoptera: Prodoxidae). *Ann. Entomol. Soc. Am.* 81:547-553.
- Walsingham, T. 1903. Review: A list of North American Lepidoptera and key to the literature of this order of insects. *Ent. Mon. Magazine* 39: 257-261.
- Webber, J.M. 1953. Yuccas of the Southwest. Agriculture Monograph No. 17, U.S. Department of Agriculture, 97 pp.
- Wershler, C. and C. Wallis. 1986. Lost River significant features assessment. Alberta Forestry, Lands and Wildlife – Public Lands Division, Edmonton, AB. 54 pp.
- Wilson, R.D. and J.F. Addicott. 1998. Regulation of mutualism between Yuccas and Yucca Moths: is oviposition behavior responsive to selective abscission of flowers? *Oikos* 81: 109-118.

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Donna Hurlburt holds a B.Sc. (Agriculture) (Nova Scotia Agricultural College, Truro, N.S.), an M.Sc. in Biology (Acadia University, Wolfville, NS) and a Ph.D. in Environmental Biology and Ecology (University of Alberta, Edmonton, AB). Her Ph.D. was followed by an NSERC Industrial Post-doctoral Fellowship with Abitibi-Bowater in Nova Scotia. Her Ph.D. assessed the mutualistic interaction between Soapweed plants and Yucca moths at the northern edge of range in Alberta and Montana.

At present, she owns and operates an environmental consulting business in Annapolis Royal, Nova Scotia. She acts as a Technical Advisor to the Alberta Soapweed and Yucca moth Recovery and Maintenance Team and continues to engage in the monitoring of the Alberta populations of Soapweed, Yucca Moth, Non-pollinating Yucca Moth and Five-spotted Bogus Yucca Moth.

Donna has participated on several COSEWIC Subcommittees, including the Arthropods and Vascular Plants Specialist Subcommittees. She is an Aboriginal Traditional Knowledge Subcommittee Co-chair and is also appointed to COSEWIC.

COLLECTIONS EXAMINED

Agriculture and Agri-Food Canada Research Lab collection, 5403 - 1st Avenue, P.O. Box 3000, Lethbridge, Alberta, T1J 4B1.

Bowman Collection, E.H. Strickland Entomological Museum, University of Alberta, CW405a Biological Sciences Centre, Edmonton, Alberta T6G 2E9.

Canadian Museum of Nature, PO Box 3443, Stn. D., Ottawa, Ontario. K1P 6P4.

Canadian National Collection of Insects, Arachnids, and Nematodes, Eastern Cereal and Oilseed Research Centre, K.W. Neatby Building, Ottawa, Ontario, K1A 0C6.

Collections of the former United States National Museum, now deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D.C., USA.

Invertebrate Zoology Collection, The Provincial Museum of Alberta. 12845-102 Avenue, Edmonton, Alberta. T5N 0M6.

Northern Forestry Centre Research Collection, 5320 - 122nd Street, Edmonton, Alberta, T6H 3S5.

Appendix 1. Populations of *Tegeticula yuccasella*, *T. corruptrix* and *Prodoxus quinquepunctellus* in Alberta and Canada. Points correspond to Figure 7.

Point	Location	Coordinates	Comments
1.	Onefour or Lost River, AB	49°00'00" N 110°26'00" W	Native, self-sustaining population of Soapweed and yucca moths
2.	Pinhorn Grazing Reserve, near Milk River, AB	49°05'12" N 110°50'04" W	Native population of Soapweed and yucca moths that suffered almost complete reproductive failure from 1998-2007 in the absence of management intervention. Deer exclosures have resulted in increased fruit production and moth emergence since 2008.

Appendix 2. Summary of data for Canadian specimens of *Tegeticula yuccasella*, *T. corruptrix* and *Prodoxus quinquepunctellus*.

Species	Locality	Date	Quantity	Collector	Collection
<i>T. yuccasella</i>	Onefour, AB	1950-07-09	3	K. Bowman	UASM
<i>T. yuccasella</i>	Onefour, AB	1950-07-04	2	K. Bowman	UASM
<i>T. yuccasella</i>	Onefour, AB	1950-06-30	4	K. Bowman	UASM
<i>T. yuccasella</i>	Onefour, AB	1950-07-02	1	K. Bowman	UASM
<i>T. yuccasella</i>	Onefour, AB	1950-07-06	2	K. Bowman	UASM
<i>T. yuccasella</i> (abdomen & dissected genitalia on slide)	Onefour, AB	1950-07-09	2	K. Bowman	UASM
<i>T. yuccasella</i>	Onefour, AB	1950-07-09	3	E.H. Strickland	UASM
<i>T. yuccasella</i>	Onefour, AB	1950-07-09	5	E.H. Strickland	CNC
<i>T. yuccasella</i>	Normandale, ON	1956-07-26	1	Freeman & Lewis	CNC
<i>T. yuccasella</i>	Queenston, ON	1933-07-12	1	Patterson	CNC
<i>T. yuccasella</i>	Simcoe, ON	1951-07-05	1	Freeman	CNC
<i>T. yuccasella</i>	Vineland Stn., ON	1940-07-24	1	Putnam	CNC
<i>T. corruptrix</i>	Lost River Valley, AB; 1 km N of Montana border	2001-06-28	2	Pohl, Macauley & Machney	NFRC
<i>T. corruptrix</i>	Onefour, AB	1950-07-09	1	A. Hewitt	AGRL
<i>T. corruptrix</i>	Onefour, AB	1950-07-09	1	K. Bowman	UASM
<i>P. quinquepunctellus</i>	Lost River Valley, AB; 1 km N of Montana border	2001-06-28	16	Pohl, Macauley & Machney	NFRC
<i>P. quinquepunctellus</i>	Lost River, AB	1950-07-09	3	A. Hewitt	AGRL
<i>P. quinquepunctellus</i>	Onefour, AB	1950-07-09	13	K. Bowman	UASM
<i>P. quinquepunctellus</i>	Onefour, AB	1950-07-09	7	R.H. Strickland	CNC
<i>P. quinquepunctellus</i>	Onefour, AB	1950-07-09	2	R.H. Strickland	UASM
<i>P. quinquepunctellus</i>	Onefour, AB	1950-07-04	1	K. Bowman	UASM
<i>P. quinquepunctellus</i>	Onefour, AB	1950-07-02	3	K. Bowman	UASM
<i>P. quinquepunctellus</i>	Onefour, AB	1950-06-28	1	K. Bowman	UASM
<i>P. decipiens</i>	Vineland, ON	1935-36	20	W.L. Putnam	CNC

NFRC – Northern Forestry Centre Research Station

AGRL – Agriculture and Agri-Food Canada Research Lab Collection

UASM – University of Alberta Strickland Museum

CNC – Canadian National Collection of Insects, Arachnids and Nematodes, Agriculture and Agri-Food Canada